Applicant File No. 001-US-02

MODULAR INFLATABLE MULTIFUNCTION FIELD-DEPLOYABLE APPARATUS AND METHODS OF MANUFACTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Serial No. 10/156,814, filed 30 May 2002 (now U.S. Patent No. 6,897,832 issued 24 May 2005), which is related to U.S. Provisional Patent Application Serial No. 60/294,440 filed May 30, 2001. This application independently claims the benefit of U.S. Provisional Patent Application Serial No. 60/403,815 filed December 04, 2002. Additionally, this application relates to co-pending PCT Patent Application Serial No. PCT/US02/16918 as filed May 30, 2002, as amended November 27, 2002 under PCT Article 19, and as amended December 30, 2002 under PCT Article 34. This application also claims the benefit of PCT Patent Application Serial No. PCT/US02/16918 as amended under PCT Article 34 on December 30, 2002. The entire specification (including Description, Drawing, and Claims) contained within each of these related applications (e.g., US Patent Application Serial No. 10/156,814; US Provisional Patent Application Serial No. 60/294,440; US Provisional Patent Application Serial No. 60/403,815; and PCT Patent Application Serial No. PCT/US02/16918), both as filed and as amended (where applicable), is hereby incorporated herein by reference.

MODULAR INFLATABLE MULTIFUNCTION FIELD-DEPLOYABLE APPARATUS AND METHODS OF MANUFACTURE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates most broadly to multifunction field-deployable tools or apparatus, which are principally configured for use as highly portable solar cooking, heating, and/or energizing apparatus, but which typically may also be reconfigured and/or redeployed by the user in the field to serve (i.e., provide a means for performing) numerous other life-enhancing or life-sustaining functions. More specifically, the present invention relates to inflatable (or otherwise collapsible), multifunction, solar energy concentrating devices, which are typically (but not necessarily) specially configured and/or re-configurable to also effectively and reliably perform one or more other functions selected from a broad range of focused electromagnetic, non-focused electromagnetic, and/or non-electromagnetic functions, thereby rendering the invention highly amenable to a broad scope of practical applications within a wide range of terrestrial and/or non-terrestrial (e.g., marine, airborne, space-based) environments.

2. RELATED ART

a. Description

The related art of interest describes various electromagnetic energy harnessing devices including several apparatus for concentrating solar energy, but none discloses the present invention. Accordingly, there remains a need for an economical field-deployable apparatus, which, in addition to being able to concentrate solar energy for heating, cooking, and/or energizing, also provides a means for performing various other life-enhancing or life-sustaining functions, and which is fully collapsible (e.g., deflatable) to greatly facilitate

portage and storage. A review of the related art reveals its many limitations and disadvantages and, thus, clearly shows that this need for a highly portable, multifunction, field-deployable apparatus remains unfulfilled, thereby underscoring the value of the present invention, which fully and uniquely meets this need.

In particular, U.S. Patent No. 3,326,624 issued on June 20, 1967, to Wladimir von Maydell et al. describes an inflatable paraboloid mirror capable of being formed into a permanently rigid structure in outer space to collect solar energy for space stations and flying bodies. The mirror has a valved annular ring, radial segmental covers or strip springs, radial heating wires, and a valved double walled mirror formed with polyester foam coated with a reflector material. The ring and mirror have internal rigid spacers. However, this apparatus is not well suited for use as a field-deployable tool because it cannot be collapsed and re-deployed after its initial deployment, it is not multifunctional, it does not provide a means for supporting and orienting the apparatus to facilitate use in a terrestrial environment, it does not provide a means for protecting the user against accidental exposure to concentrated electromagnetic radiation, and both its mechanical structure and its means of deployment are generally too complex to allow the device to be economically produced for wide use by the general public.

Other related art exhibiting many of these limitations and disadvantages include:

U.S. Patent No. 5,920,294 issued on July 6, 1999, to Bibb B. Allen describes a space antenna having an interior tensioned multiple cord attachment in a balloon which uses Mylar® for electromagnetic and solar energy applications in a first embodiment. A second embodiment utilizes an exterior tensioned cord attachment to a spacecraft of an antenna reflector of a gold-plated molybdenum or graphite wire mesh inside an inflated toroidal support balloon which uses Mylar® for electromagnetic and solar energy applications. Note that the mechanical attachments (tensioned cord-ties) used to deploy the reflector are generally too complex and also too great in number to permit economical construction of a device intended for general use by

the public. Also, no means is provided for supporting and orienting the apparatus in a terrestrial environment.

U.S. Patent No. 4,352,112 issued on September 28, 1982, to Fritz Leonhardt et al. describes a large reflector having an inner face of either a polished aluminum sheet or a plastic sheet backed by individual membrane segments of a rigid foam backing having a curved concave surface and an opening in its center. Two membranes formed as concave or convex reflectors are used to reflect and concentrate solar rays to a heat absorber, heat exchanger and the like. Note that this patent is primarily a means for producing parabolic reflectors from flat planar sheets of material, and shows various rigid means for supporting and operating such reflective membranes. Further, it does not represent a portable device.

U.S. Patent No. 2,977,596 issued on March 28, 1961, to Harold D. Justice describes an inflatable circular antenna saucer on a transmitter or receiver base. Note that the rigid support frame of the apparatus is not significantly collapsible for portage and storage, and the reflector structure contains unnecessary internal webbing, which is not economical to produce.

U.S. Patent No. 3,005,987 issued on October 24, 1961, to Kent M. Mack et al. describes an inflatable antenna assembly comprising a radome covering an inflatable elliptical tubular membrane support having structural lacing and two concave flexible non-conducting sheets, wherein one sheet is coated with vaporized aluminum. Note that the apparatus is not significantly collapsible for portage and storage, the reflector structure contains tensioning cords, which are unnecessary for use as a solar concentrator, and the radome generally inhibits or prohibits use as a broad-spectrum solar energy concentrator.

U.S. Patent No. 3,056,131 issued on September 25, 1962, to Ralph L. McCreary describes an inflatable reflector for electromagnetic radiation comprising two concave thin sheets of flexible plastic material, wherein at least one sheet has a parabolic shape. Note that the rigid support frame of the apparatus is not significantly collapsible for portage and storage. Also, no means is provided for adjustably supporting

and orienting the apparatus in a terrestrial environment.

U.S. Patent No. 3,221,333 issued on November 30, 1965, to Desmond M. Brown describes an inflatable radio antenna comprising an oblate bag aerial including a pair of spaced parallel insulating planar surfaces connected to a medial portion and having two antenna elements mounted parallel to form a capacitive plate antenna. Note that this apparatus is primarily a means for producing a capacitive aerial antenna. It does not have a means for concentrating solar energy, such as a parabolic reflector, nor any means for performing any other functions except its primary (sole) use as a capacitive aerial antenna.

U.S. Patent No. 3,413,645 issued on November 26, 1968, to Richard J. Koehler describes an elongated inflatable parabolic radar antenna toroid assembly providing a small wave energy aperture in one plane and a larger wave energy aperture in a perpendicular plane. Note that this apparatus is not significantly collapsible for portage and storage, and that the reflector's support structure generally inhibits or prohibits use as a broad-spectrum solar energy concentrator.

U.S. Patent No. 3,471,860 issued on October 7, 1969, to Floyd D. Amburgey describes a reflector antenna having a variable or flexible surface, the geometrical shape of which may be changed by air pressure or a partial vacuum behind the flexible membrane for the purpose of obtaining the best reception from this antenna type. Note that this patent is primarily a means for producing an adjustable-focal-length parabolic reflector from flat planar sheets of material. It does not represent a significantly collapsible portable device.

U.S. Patent No. 4,672,389 issued on June 9, 1987, to David N. Ulry describes an inflatable reflector apparatus and a method of manufacture. A super-ambient pressure is maintained within the envelope, which is maintained by a compression frame member. Note that the rigid support frame of the apparatus is not significantly collapsible for portage and storage, and the transparent membrane of the super-ambient reflector structure limits efficiency when used as a solar energy concentrator.

U.S. Patent No. 4,741,609 issued on May 3, 1988, to Daniel

V. Sallis describes a stretched membrane heliostat having a membrane mounted on a circular frame, there being a double-walled portion of the membrane that extends in a circle near the periphery of the membrane to form a bladder that is inflatable to tension the membrane. Note that the rigid support frame of the apparatus is not significantly collapsible for portage and storage.

U.S. Patent No. 4,755,819 issued on July 5, 1988, to Marco C. Bernasconi et al. describes a parabolically-shaped reflector antenna intended for space vehicle applications. The device is inflated by a gas in space to form an antenna reflector and an antenna radome stabilized by a rigidizing torus. The covering material is a resin-impregnated fabric which when heated by the sun polymerizes to render the reflector antenna stable and requires no gas pressure to keep its shape. Note that this apparatus is not significantly collapsible for portage and storage, it is too complex to yield a sufficiently economical field-deployable tool for use by the general public, and the radome generally inhibits or prohibits use as a broad-spectrum solar energy concentrator.

U.S. Patent No. 5,276,600 issued on January 4, 1994, to Takase Mitsuo et al. describes a planar reflector composed of a base and a flexible polymeric plastic substrate having a highly reflective silver layer formed thereon and overlaid on the base with an adhesive layer interposed between the two layers. Note that this patent is primarily a means for producing reflectors having a small radius of curvature from multi-layer planar sheets of material. It does not represent a functional collapsible reflector apparatus.

U.S. Patent No. 5,893,360 issued on April 13, 1999, to O'Malley O. Stoumen et al. describes an inflatable solar oven comprising two sheets of flexible material sealed at their edges. The top sheet is clear and the bottom sheet has a reflective layer. Note that this apparatus exhibits an extremely clumsy or cumbersome method of cooking, and the functionality of the device is easily impaired by vapors, which, after being emitted from the items being heated or cooked within the device, may condense on the transparent membrane of the

device, thereby diffusing the impinging solar radiation, thus preventing effective concentration. Further, the device is not multifunctional.

U.S. Patent No. 6,150,995 issued on November 21, 2000, to L. Dwight Gilger describes a combined photovoltaic array and a deployable perimeter truss RF reflector. Note that this structure is highly complex in light of its two simple functions, and it is generally not suitable for use as a terrestrial field-deployable tool.

U.S. Patent No. 6,219,009 issued on April 17, 2001, to John Shipley et al. describes a tensioned cord and tie attachment of a collapsible antenna reflector to an inflatable radial truss support structure. Note, again, that the mechanical attachments (tensioned cord-ties) used to deploy the reflector are generally too complex to permit economical construction of a device intended for general use by the public. Also, no means is provided for supporting and orienting the apparatus in a terrestrial environment.

U.K. Patent Application No. 758,090 published on September 26, 1956, for Charles T. Suchy et al. describes an inflatable balloon having arranged within a radio aerial. Note that this apparatus does not have a concentrating reflector.

France Patent Application No. 1.048.681 published on December 23, 1953, for Adnan Tarcici describes a reflector for concentrating solar energy for cooking when camping. Note that this apparatus is not significantly collapsible for portage and storage.

Japan Patent Application No. 59-97205 published on June 5, 1984, for Yasuo Nagazumi describes a parabolic antenna having an airtight chamber filled with nitrogen and demarcated with a radiating aluminum casing and a heat-insulating mirror. Note that this apparatus is not significantly collapsible for portage and storage and is not suitable for concentrating solar energy.

b. Summary of Disadvantages of Prior Art

In short, the disadvantages of prior art generally include, among others, one or more of the following limitations:

(a) the device or apparatus generally is not multifunctional in nature, i.e., it is generally limited to either a single function or perhaps two or more closely related functions;

(b) the apparatus is not suitably or sufficiently collapsible to permit easy transport to and from the field, or allow convenient storage when not in use;

(c) the apparatus is not easily reusable or re-deployable, i.e., the apparatus cannot be collapsed after its initial deployment to facilitate portage to an alternate location or to compactly store for future use;

(d) the apparatus has no lightweight collapsible means for supporting and orienting the apparatus to facilitate use in a terrestrial environment, and/or it does not employ other features to facilitate use by persons having limited experience or knowledge, such as simple well-known inflation valves;

(e) the apparatus has no means for protecting the user from accidental exposure to highly concentrated electromagnetic radiation, thereby posing a safety hazard;

(f) the apparatus exhibits limited efficiency when concentrating broad-spectrum solar radiation as a result of having one or more intervening layers in its optical path, such as a transparent membrane or radome;

(g) the apparatus exhibits unnecessary structural complexity, thereby rendering the apparatus uneconomical to produce for wide use by the general public; and/or

(h) the apparatus is generally not suitably robust or sufficiently durable for rapid deployment into the field, such as by air drop, nor does the apparatus provide a means for easily repairing the device in the field using integral rapid-repair materials in the event of damage.

In contrast, each of these disadvantages or limitations of prior art are overcome by the present invention.

SUMMARY OF THE INVENTION

a. General Description

The present invention is a modular, inflatable, multifunction, field-deployable apparatus, which primarily provides an economical means for concentrating solar energy for heating, cooking, and/or energizing, but which also typically provides various means for performing other life-enhancing or life-sustaining functions, and which is generally fully collapsible (e.g., deflatable) to greatly facilitate portage and storage. Briefly, the modular, inflatable, multifunction, field-deployable apparatus of the present invention typically has as its primary functional module a basic inflatable, multifunction, parabolic reflector apparatus, such as disclosed in our previous (cross-referenced) applications. The present invention typically further includes one or more optional, preferably removably attached, accessory modules and/or elements, such as an inflatable (or otherwise collapsible) means for supporting and orienting the basic inflatable reflector apparatus, an inflatable (or otherwise collapsible) means for protecting the user from accidental exposure to highly concentrated electromagnetic (e.g., solar) radiation at or near the focal point of the basic reflector apparatus, an inflatable (or otherwise collapsible) means for supporting materials or accessory elements in proximity to the focal point, and an inflatable (or otherwise collapsible) protective cover.

Regarding functionality, briefly note that both the basic inflatable reflector apparatus of the basic invention and, thus, the modular field-deployable apparatus of the present invention are primarily configured for use as highly portable solar cooking, heating, and/or energizing apparatus. However, both the basic reflector apparatus and the modular field-deployable apparatus are typically (but not necessarily) specially configured to also effectively and reliably perform, either alone or in concert with various optional accessory elements, one or more other functions selected from a broad range of focused electromagnetic, non-focused electromagnetic, and non-

electromagnetic functions. Hence, both the basic reflector apparatus and the modular field-deployable apparatus can serve as highly portable multifunction tools, each of which is highly amenable to a broad scope of practical applications; however, the modular apparatus of the present invention offers greater versatility, safety, and ease of use.

In greater detail, the present invention is generally functionally optimized (as is the basic invention) for concentrating, focusing, and/or beaming radiant electromagnetic energy and is effective over a wide range of the electromagnetic spectrum from radio frequency (RF) radiation through ultraviolet (UV) radiation including broad-spectrum solar energy. However, as indicated above, the present invention (and the basic invention) can also effectively and reliably perform numerous other functions not related to concentrating, focusing, and beaming radiant electromagnetic energy. Focused electromagnetic applications of the present invention typically include 1) concentrating broad-spectrum (e.g., solar) radiation for heating, cooking, sterilizing, distilling, processing materials, generating electrical power, and/or the like, (2) manipulating radio and/or microwave frequency radiation for enhancing the transmission and reception of radio signals and/or other electromagnetic communications, and/or (3) manipulating visible-spectrum radiation for enhancing vision in low-light environments, projecting optical signals or images, and/or other optical purposes, such as using the apparatus as a convex mirror to extend the user's field of vision for surveillance and/or safely. Non-focused electromagnetic applications typically include 1) use as an emergency thermal blanket, shelter, incubator, greenhouse, and/or the like, (2) use as an electromagnetic energy shield, and/or (3) use as an electrostatic insulator. Non-electromagnetic applications typically include (1) the collection, storage, and/or processing of water or other substantially fluidic materials, (2) use as a shelter to protect persons, equipment, materials, and/or other items from inclement weather and/or other environmental elements, (3) use as a soft or compliant support such as a bed, cradle, inflatable cast (for immobilizing a broken limb), and

the like, (4) use as a water flotation device or water boat, (5) use as a portable fermentor apparatus for producing fuels, medicines, beverages, and/or other materials, (6) use as an inflatable wind turbine for producing electrical and/or mechanical power, and/or (7) use as a directional sound amplification device. The invention contemplates numerous other uses as discussed hereinbelow and as readily apparent to a user of the apparatus. However, it is emphasized that any particular embodiment or manifestation of the present invention need not perform all such functions, i.e., a particular embodiment can be configured to perform a limited number or subset of these functions without departing from the nature of the invention. Further, as will be shown below, it should be noted that although the basic reflector apparatus is generally the primary functional module of the modular field-deployable apparatus, the present invention (i.e., the modular field-deployable apparatus) can optionally be reconfigured without a basic reflector apparatus by the user in the field (or by the factory) to perform various non-focused electromagnetic and/or non-electromagnetic functions, for example, use as a water flotation device or use as part of a wind turbine apparatus, without departing from the nature of the invention.

Regarding physical construction, first note that each of the modular structures of the present invention are generally optimized to minimize weight, non-deployed volume, and production cost, while simultaneously maximizing operational performance, versatility, and safety. To achieve such optimization, the primary modules of the present invention are typically made from one or more lightweight inflatable structures (such as an inflatable ring), thin flexible (e.g., pressure-deployable) membranes, and/or other easily collapsible, lightweight structures. An excellent example of such structural optimization is the basic inflatable reflector apparatus in a preferred first main embodiment configuration, wherein two pressure-deformable (i.e., pressure-deployable) membranes, at least one of which is reflective, are utilized in conjunction with the inner portion of an inflatable support ring to form a highly efficient central reflector chamber, which generally can

be inflated to either sub-ambient pressure (as required for most applications) or super-ambient pressure to deploy the reflective membrane(s). Note that by using the inner portion of the support ring to form an integral part of the highly efficient sub-ambient-pressurizable reflector chamber, the first embodiment of the basic reflector apparatus can be produced very economically from a minimum number or parts while maximizing weight-specific power output.

As another example, a second main embodiment of the basic reflector apparatus utilizes at least one reflective membrane and at least one transparent membrane to form a central reflector chamber, which generally can be inflated only to super-ambient pressure to deploy the reflective membrane. Although generally less efficient than the first embodiment when used for concentrating broad-spectrum electromagnetic energy, the primary structure of the second embodiment of the basic reflector apparatus can be made extremely economically from as few as two sheets of material. Additionally, both embodiments of the basic reflector apparatus generally employ one or more reflective membranes which are pre-formed substantially into the shape of a paraboloid to enhance safety, facilitate operation, and reduce structural loading of the membranes on the support ring. (It is noted that a "pre-formed" pressure-deformable membrane is a membrane which is fabricated to substantially embody or possess its pressure-deformed shape, i.e., its deployed surface contour, prior to the application of significant differential pressure across the membrane.) As noted above, the other modules of the present invention are also typically constructed from similar lightweight inflatable structures and/or pressure-deployable membranes to achieve such structural optimization; however, it should be further noted that particular modules (or components thereof) are also sized to substantially match, where possible, other modules and/or components of the present invention, both to further reduce fabrication cost by minimizing the number of different elements required to construct the modular apparatus, and to allow similarly sized modules to be easily interchanged to increase versatility of the modular apparatus and/or to facilitate rapid

substitution of one or more modules in the event of damage.

To enable the various modules of the present invention to operate as a unit, each module typically includes one or more attachment means for connecting to other modules of the apparatus, for attaching accessory elements, and/or for securing and stabilizing the apparatus to promote safe operation. Additionally, each inflatable and/or pressure-deployable module of the apparatus requires at least one inflation means or pressure-adjusting means such as, for example, a simple well-known plug valve, a manual or automatic pump, a gas canister, and/or the like.

To increase performance, to further enhance safety, to facilitate use, to reduce production cost, and/or to enable the modular field-deployable apparatus to perform additional functions, the present invention contemplates that numerous alternate configurations, optional features, and/or accessory elements typically can be substituted for, incorporated into, and/or used in concert with the various modules of the present invention.

Regarding alternate configurations, note, for example, that the use of non-pre-formed (i.e., planar) elastic reflective membranes is contemplated to enable the basic reflector apparatus to have a variable focal length. Further, the use of pre-formed, non-parabolic reflective membranes (e.g., reflective membranes having surfaces which are spherical, undulating, a series of conic sections, faceted, and/or the like) is contemplated to limit the maximum degree of concentration to further enhance safety. In addition, the invention also contemplates various novel methods of manufacture for the various modules. More specifically, various fabrication processes, such as those disclosed in our previous (cross-referenced) applications, may be employed to economically produce the present invention primarily from multiple, thin, flexible (e.g., pressure-deformable) membranes.

Regarding optional features and/or accessory elements, note that such elements can be either integrally incorporated within or removably attached to the various modules of the present invention. Also note that the various modules of the apparatus

may be integrated, such as to permit simultaneous inflation of the integrated, interconnected modules.

Specific portable apparatus are shown hereinbelow which greatly facilitate or enable a wide range of useful applications. However, the invention contemplates that many other portable apparatus may be provided for various purposes by judiciously combining one or more of the modules of the modular field-deployable apparatus (or alternate configurations thereof) with any of the numerous optional features and/or accessory elements of the present and/or basic invention, i.e., the invention is not limited to the specific examples shown and/or described herein.

Ultimately, the present invention serves as a highly portable, field-deployable, multi-function, multi-purpose apparatus or tool, which can quickly and economically provide in the field (or other partially or significantly infrastructure-deprived environment) at least one life-enhancing or life-sustaining function or utility. More specifically, the invention can perform many of the life-sustaining functions and/or utilities routinely provided by much more massive, semi-portable apparatus and/or substantially fixed elements of infrastructure that are typically found within highly infrastructure-rich environments. Consequently, the highly portable multifunction apparatus of the present invention can rapidly, effectively, and economically replace and/or supplement, either temporarily or permanently, many of these life-sustaining apparatus and/or elements of infrastructure, examples of which include various domestic (i.e., household) appliances and/or other housewares; research, commercial, industrial, recreational, and/or military equipment; municipal power, water, and/or communication utilities; basic shelter from inclement whether or other environmental elements; and/or the like. Accordingly, the present invention is ideally and uniquely suited to facilitate a broad range of activities including, for example, remote field work, emergency response, disaster relief, outdoor recreation (such as camping, backpacking, picnicking, boating, and/or the like), education, and/or other activities in terrestrial and/or non-terrestrial

(e.g., marine, airborne, space-based) environments.

b. Typical Advantages Over Prior Art

Hence, the modular inflatable multifunction apparatus comprising the present invention is generally superior to the related art in at least seven very significant respects.

First, the present invention is superior to the related art as a result of its highly multifunctional, multipurpose nature. It is noted that the preferred and alternate embodiments of the present invention have numerous electromagnetic and non-electromagnetic utilities. In contrast, all related art is significantly more limited with respect to utilities and applications thereof. In greater detail, it is emphasized that none of the prior art makes any references to, or accommodations for, performing non-electromagnetic functions, such as water collection and storage, which is but one of many critically important aspects of the present invention when the apparatus is deployed in the field as a multifunctional survival tool. In addition, the modular nature of the present invention allows the various modules of the apparatus to be used simultaneously for similar and/or radically different functions; however, prior art contains no such provision.

Second, the present invention is superior to the related art as a result of its extremely lightweight and compactly foldable construction, which greatly facilitates portage and storage. As an example, note that a pocket-sized version of the basic inflatable reflector apparatus having a mass of approximately 100 grams and measuring only 8.5cm by 12.0cm by 1.0cm when fully collapsed can be inflated to yield a fully deployed device having a 120cm diameter primary reflector providing 1000 watts of highly concentrated broad-spectrum radiant energy when utilized terrestrially as a solar energy concentrating device. It is noted that such a device can thus provide an unprecedented mass-specific power output approximating 10000 watts per kilogram, depending on the specific thickness and material of construction (e.g., a 13-

micron-thick nylon/polyethylene co-extruded membrane), and a non-deployed, compactly folded, volume-specific power output (i.e., non-deployed power density) approximating 10 megawatts per cubic meter. As a result, a single cargo air lifter can, for example, airdrop in a single load a sufficient quantity of the apparatuses to capture and concentrate well over 100 megawatts of solar energy. Although a modular apparatus incorporating several inflatable accessory modules generally has a lower weight-specific and volume-specific power output than the basic inflatable reflector apparatus, it should be noted that such inflatable accessory modules of the modular apparatus optionally can be constructed from one or more modified basic reflector apparatuses such that the modified modular apparatus can be reconfigured as a plurality of basic inflatable reflector apparatuses, which substantially achieve the same high weight-specific and volume-specific power output of the primary basic inflatable reflector apparatus.

Third, the present invention is superior to the related art as a result of its precisely pre-formed reflective membranes and other optional features, which greatly increase the operational safety of the device. More specifically, the use of pre-formed parabolic reflective membranes (instead of planar membranes as generally used in related art) allows the device to have (and can limit the device to) relatively short and substantially fixed focal lengths, thereby enabling the user to maintain greater control over the location of any potentially dangerous, high concentrations of radiant energy. In addition, pre-formed, non-parabolic reflective membranes may be used to limit the maximum degree of energy concentration to lower and, thus, safer levels. Further, the use of optional integral safety cages, safety covers, and/or other safety features significantly reduces the risk of accidental exposure to high concentrations of electromagnetic radiation. Again, such features and their associated benefits are not contemplated by prior art.

Fourth, the present invention is superior to the related art in that it is easier to deploy (e.g., inflate) and operate. Note that by using pre-formed reflective membranes, such reflective membranes can be fully deployed using significantly

less differential pressure across the membranes, thereby facilitating proper inflation. In addition, various optional elements may be incorporated into the device, which further enhance ease-of-use during deployment and/or operation. For example, such elements include (1) various novel means for supporting and/or orienting the device, (2) various novel apparatus for holding materials or accessory elements in proximity to the focal point, and (3) the use of simple, well-known inflation valves, which greatly facilitate deployment, even by persons having limited education or prior experience with solar concentrating apparatus. In contrast, except for the occasional use of well-known focal point supports, prior art neither contemplates nor anticipates such elements or the benefits thereof.

Fifth, the present invention, when employing a first embodiment configuration of the basic reflector apparatus, is more efficient in that it eliminates all loss-inducing intervening layers as contained within the optical paths of all closely related prior art, i.e., art employing pressure-deformable reflective membranes supported by an inflatable ring. Note that by employing a sub-ambient pressure reflector chamber, as is used in the first embodiment of the basic reflector apparatus, sunlight or other electromagnetic radiation can travel, unobstructed, from the energy source to the reflector and then to the target. Accordingly, the first embodiment of the basic reflector apparatus causes no (i.e., zero) losses of radiant electromagnetic energy as such energy travels to and from the reflector. In contrast, most related art requires sunlight or other electromagnetic radiation to pass through the transparent membrane of a super-ambient reflector chamber on its way to and from the reflector, thereby resulting in a plurality of losses. The remaining prior art, although utilizing a sub-ambient pressure reflector chamber, also requires the electromagnetic energy to pass through at least one intervening layer, such as a radome, again resulting in a plurality of losses. In general, these losses include the reflection, absorption, and diffusion of electromagnetic radiation by the

intervening layer as the radiation travels to and from the reflector. Ultimately, the intervening layers of prior art are typically responsible for reducing the efficiency of such devices by as much as twenty percent, or more, depending upon the wavelength of the impinging radiation and the transmission characteristics of the material or materials comprising the intervening layer.

Sixth, the present invention (most notably its basic reflector apparatus) is superior to the related art as a result of its extremely simple, highly integrated structure, which has been specially configured to facilitate high-speed mass-production, thereby making the device very economical to produce. Note that the designs specified in the related art do not demonstrate the high degree of integration and resulting simplicity of construction to the extent specified herein for the present invention. Also note that the relative simplicity of the present invention is due, in part, to the fact that the reflective membrane of its basic reflector apparatus can be deformed into a substantially parabolic surface utilizing only the surrounding ambient (e.g., atmospheric) pressure and simple, manually-operated, integral valves. In contrast, all related art relies on complex mechanical arrangements, complex electrostatic systems, or complex pressure adjusting systems to deform the reflective membrane into a substantially parabolic surface.

Seventh, the present invention is superior to prior art as a result of possessing a superior degree of robustness, especially when deployed into the field via airdrop or other potentially high-acceleration-inducing delivery methods. Note that such robustness of design is a result of the nearly exclusive use of thin flexible membranes (instead of rigid structures) to produce the apparatus. Further, in the event of damage, the apparatus is also superior to prior art in that it exhibits superior maintainability, which is achieved by incorporating an integral means for rapidly repairing the apparatus in the field. In contrast, the related art provides

no such means for conveniently maintaining the apparatus in the field.

It should be noted that each of the above aspects of the present invention, taken separately, represents a significant improvement over prior art. However, in combination, these superior aspects of the present invention represent an enormous improvement over prior art, the significance of which should not be underestimated. More specifically, as a result of possessing all of the noted improvements over prior art, the present invention can effectively serve as a highly multifunctional, highly portable, generally safe-to-operate, easy-to-use, high-performance, and highly economical tool -- a tool which has the ability to significantly enhance one's ability to enjoy and/or survive a variety of difficult or demanding physical environments, which, for a variety of reasons, have few if any of the typical life-sustaining facilities or elements of infrastructure upon which much of humanity is presently highly dependent. In particular, the apparatus offers greatest benefits to persons who are suddenly and unexpectedly forced to dwell in regions of the world in which basic food preparation facilities, potable water systems, or other critical elements of the local infrastructure have been either destroyed or otherwise rendered inoperable, whether as a result of war, natural disaster, or other crisis. Under such circumstances, it should be noted that the efficacy with which emergency supplies and temporary infrastructure can be reestablished within the disaster area directly affects the quality of life and, more importantly, the survival rate of the persons located in the affected region. Ultimately, to alleviate as much general hardship as possible, but also to minimize the mortality rate, substitute temporary-use facilities need to be reestablished throughout the affected region in sufficient quantities, and with a minimum of time, effort, and expense. Due to its low cost, ease-of-use, and high degree of portability, the multifunction device disclosed herein is ideally and uniquely suited to facilitate such emergency or disaster relief efforts. As a result, the instant invention provides a highly effective

method for meeting this unending global need -- an aspect of the invention that is neither contemplated nor anticipated by prior art.

The present invention can also be of great benefit to individuals living, working, or traveling in underdeveloped or neglected parts of the world. For the outdoorsman or explorer, the modular field-deployable apparatus can serve as an invaluable multifunctional survival tool. In addition, as noted above, the apparatus can offer many benefits to persons who choose to participate in a variety of outdoor recreational activities for which portable food preparation facilities and/or other functions of the present invention are either needed or desired. Further, it should be noted that the highly economical apparatus is ideally suited for use as an instructional aide for teaching students or other interested parties about solar energy. Considering the world's dwindling supply of fossil fuels and other conventional fuels -- especially in conjunction with the present ever-increasing global demand for energy -- worldwide education about solar energy is becoming increasingly necessary to protect the environment, sustain the global economy, and ensure a reasonable quality of life for all creatures inhabiting the Earth. Once again, these additional purposes and benefits are neither contemplated nor anticipated by prior art.

As one reads subsequent sections of this document, it will become quite clear that the modular field-deployable apparatus is also superior to the related art in a variety of other ways including, among other items, various novel methods of manufacturing, deploying, and using the modular apparatus.

c. Specific Objects and Advantages of the Invention:

Accordingly, it is a principal object of the present invention to provide a highly portable (e.g., inflatable or

otherwise collapsible), multifunction, multipurpose, field-deployable apparatus and fabrication methods thereof, which is generally optimized for use as a substantially parabolic reflector to focus electromagnetic energy from radio frequency radiation (RF) through ultraviolet radiation (UV) including solar radiation (or a predetermined subset thereof), but which typically can also be used for numerous other electromagnetic and/or non-electromagnetic utilities. Regarding the multi-functional nature of this invention, specific (but optional) objects of the present invention are:

(a) to provide a highly portable multifunction apparatus for concentrating broad-spectrum (e.g., solar) radiation for cooking, heating, sterilizing, distilling, material processing, and/or for other purposes requiring or benefiting from the application of radiant heat, which may optionally utilize various accoutrements specially configured for absorbing concentrated solar radiation including, for example, a solar oven or autoclave having a high-emissivity (generally blackened) energy-absorbing external surface;

(b) to provide a portable multifunction apparatus for generating electrical power utilizing turboelectric, thermoelectric, and/or photoelectric devices;

(c) to provide a portable multifunction apparatus, which can be utilized to concentrate light radiating from a relatively dim source, such as a street lamp, to operate (and/or recharge) an otherwise inoperable, low-power, photovoltaic device, such as a handheld calculator;

(d) to provide a portable multifunction apparatus, which can be used for enhancing or enabling radio, microwave, and/or satellite communications (including use of one or more apparatus as a relay station), and/or for enabling radio-telescopy;

(e) to provide a portable multifunction apparatus for enhancing vision in darkened environments by concentrating visible light radiating from a dim source, such as a crescent moon, onto an object to be viewed;

(f) to provide a portable multifunction apparatus for

enhancing vision in darkened environments by projecting light from non-collimated sources, such as a candle, into dark environments;

(g) to provide a highly portable multifunction apparatus for enabling or enhancing optical signal communications, such as when used with a non-collimated light source held at the focal point to form a signal beacon, and optionally further including colored, textured, polarized, and/or image-containing transparent and/or reflective membrane(s) to enhance signaling and/or to provide artistic lighting or imaging;

(h) to provide a portable multifunction apparatus employing a waveguide system to capture and deliver pan-chromatic visible light (or other useful spectral range of radiation) to interior, subterranean, and/or underwater environments to enhance vision and/or to operate equipment such as an optical image projector;

(i) to provide a portable multifunction apparatus, which can serve as a multi-layer emergency thermal blanket, electrostatic insulator, and/or electromagnetic energy shield to protect a person or object, but which also allows a person or object to hide from an infrared (IR) camera or otherwise be shielded from an electromagnetic imaging or detection device;

(j) to provide a portable multifunction apparatus, which can serve as a soft, compliant support for persons or objects, including use as a bed, cradle, seat, inflatable cast (for immobilizing a broken limb), or the like;

(k) to provide a portable multifunction apparatus, which can be used as a water flotation device, boat, or snow sled;

(l) to provide a portable multifunction apparatus, which can be used to capture, store, process, and/or distribute water, other liquids, and/or certain solid materials, for which various optional accoutrements (such as catchment rings, gutters, funnels, filters, tubes, valves, pumps, and the like) can be either integrally or removably incorporated into the apparatus;

(m) to provide a portable multifunction apparatus

incorporating a high-emissivity surface, such as a matte black surface, which can be used to collect water at night by radiative condensation processes;

(n) to provide a portable multifunction apparatus, which can be used as a fermentor, which in conjunction with the distillation function noted above, allows the apparatus to produce high grade spirits for fuel, medicinal, and other purposes;

(o) to provide a portable multifunction apparatus for the directional amplification of sound;

(p) to provide a portable multifunction apparatus optionally incorporating one or more pressure-deformable, planar, reflective membranes to allow the device to have a variable focal length;

(q) to provide a portable multifunction apparatus, which can be used as a thermal shelter, incubator, hydroponic growing chamber, greenhouse, frost shield, and/or general shelter from inclement weather or other environmental elements (e.g., mosquitoes, other biting insects, dust, debris, sunlight, etc.);

(r) to provide a portable multifunction apparatus, which can be used as a dehydrator, dryer, curing chamber, and/or sealed or vented work chamber;

(s) to provide a portable multifunction apparatus, which can be used as an optionally camouflaged wildlife viewing/hunting blind, animal cage, terrarium, aquarium, and/or aquatic growth chamber;

(t) to provide a portable multifunction apparatus, which can be used as a wind turbine to produce electrical and/or mechanical power; and/or

(u) to provide a portable multifunction apparatus optionally incorporating one or more one-way valves to facilitate or enable use of the apparatus as a fluid pump.

A second main object of the invention is to provide a multifunction apparatus which optionally is extremely lightweight, fully collapsible, and compactly foldable so as to greatly facilitate portage and storage, thereby providing a high performance apparatus which is ideally suited to camping,

backpacking, picnicking, boating, emergency use, disaster relief, and/or other situations (terrestrial or space-based) for which high mass-specific and/or high volume-specific performance is critical. Regarding portage and storage, specific (but optional) objects of this invention are:

(a) to provide a multifunctional apparatus having a primary structure comprised entirely of thin and/or very thin, high-strength membranes to minimize weight;

(b) to provide a multi-functional apparatus, which is inflatable (i.e., rigidizable and/or otherwise deployable) by using pressurized gas which generally need not (but may) be carried with the device;

(c) to provide a multifunctional apparatus, which is fully collapsible and compactly foldable when not in use to minimize volume;

(d) to provide a multifunctional apparatus which, due to its extremely low weight and stored (non-deployed) volume, yields very high mass-specific and volume-specific performance approximating 10000 watts per kilogram and 10 megawatts per cubic meter, respectively, when used terrestrially as a broad-spectrum solar concentrator; and/or

(e) to provide a multifunctional device having extremely lightweight and compact inflation valves, for example, valves made from membranous material and including an interlocking tongue-and-groove (i.e., Ziploc®-type), clamped or tied, or self-sealing type closure mechanism.

A third main object of the invention is to provide a multifunctional apparatus, which optionally is safer to operate, transport, and/or store. Regarding safety, specific (but optional) objects of this invention are:

(a) to provide a portable multifunctional apparatus having an integral safety cage (preferably inflatable or otherwise fully collapsible), which forms a physical barrier around the focal point, thereby preventing accidental exposure to potentially dangerous concentrations of electromagnetic

radiation;

(b) to provide a portable multifunctional apparatus having an integral safety cover to block radiation from striking the reflective membrane(s) when the device is not in use, thereby preventing the formation of and, thus, the risk of accidental exposure to potentially dangerous concentrations of electromagnetic radiation at or near the focal point;

(c) to provide a portable multifunctional apparatus having an integral reflector wrinkling mechanism for distorting the reflective membranes when not fully deployed (pressurized), thereby once again substantially preventing the formation of any unintentional, potentially dangerous concentrations of electromagnetic energy;

(d) to provide a portable multifunctional apparatus having one or more pre-formed parabolic reflective membranes, which limit the device to substantially fixed, short focal lengths, thereby enhancing safety by giving the operator greater control of the location of the highly concentrated energy at the focal point;

(e) to provide a portable multifunctional apparatus having one or more pre-formed, non-parabolic reflective membranes to limit the maximum degree of energy concentration to lower and, thus, safer levels;

(f) to provide a portable multifunctional apparatus having one or more means for off-axis light attenuation such as, for example, an off-axis light attenuation grating for attenuating power when the device is positioned off-axis, and/or a darkened transparent film for attenuating reflected light when viewing from a position substantially off-axis;

(g) to provide a portable multifunctional apparatus having one or more means for blocking and/or redirecting energy in proximity to the focal point so as to provide a quick power shutoff means and/or to capture and redirect stray electromagnetic rays (which also can improve performance); and/or

(h) to provide a portable multifunctional apparatus having redundant inflatable (or otherwise collapsible) support structures (e.g., independent pressure envelopes) to mitigate the risk of catastrophic collapse or other failure.

A fourth main object of the invention is to provide a portable multifunctional apparatus that optionally is easier to deploy and/or operate. Regarding ease of use, specific (but optional) objects of this invention are:

(a) to provide an apparatus having various integral securing and storage features such as handles, apertured tabs, ties, weighting and storage pouches (especially those which are lightweight, compact, and can be made from extensions of the membranes out of which the apparatus is composed);

(b) to provide an apparatus having various integral accessory hardware attachment devices such as clevises, clips, brackets, sockets, hook-and-loop patches, and other common fastening mechanisms (especially those which are collapsible to facilitate portage and storage);

(c) to provide an apparatus having various lightweight, portable mechanisms for supporting and orienting the device including, for example, an inflatable adjustable dipody support, a stack of inflatable tapered support/leveling rings, and/or an inflatable (or otherwise collapsible) spherical mounting element with a separate, optionally inflatable (floating), support ring;

(d) to provide an apparatus having lightweight, portable mechanisms for holding various items and/or accoutrements at or near the focal point including, for example, a collapsible, multipurpose rotisserie / kettle support, a collapsible multi-leg focal point support, and/or an inflatable focal point support;

(e) to provide an apparatus having one or more pre-formed, pressure-deformable reflective membranes, which can be fully deployed using significantly lower differential pressures across the membranes than devices employing planar reflective membranes, thus facilitating proper inflation;

(f) to provide an apparatus having integral or removably attached orientating and alignment features, such as a visual alignment guide, inclinometer, level, and/or magnetic compass, to facilitate alignment with an electromagnetic source and/or target, and/or for orienting the device for other purposes;

(g) to provide an apparatus having a light/heat intensity controller such as a louver or iris mechanism which is manually or automatically controlled;

(h) to provide an apparatus having various integrally or separately attached electronic and/or mechanical elements (to facilitate various applications) including but not limited to photovoltaic cells, electrical batteries, electric pumps, fans, drivers, timers, thermostats, controllers, and/or other useful devices; and/or

(i) to provide an apparatus having a lightweight means for automated sun tracking.

A fifth main object of the invention is to provide a portable multifunctional apparatus, which optionally is more efficient, wherein two pressure deformable membranes are utilized to form a sub-ambient concave-concave reflector chamber configuration, thereby eliminating the plurality of losses inherent in devices having one or more intervening layers in the optical path, such as a transparent membrane of a super-ambient reflector chamber, through which light must pass at least once on its way to or from the focal point.

A sixth main object of the invention is to provide a portable multifunctional apparatus, which optionally is highly economical by virtue of its extremely simple, highly integrated construction, and which can thus be made universally available for both routine use as well as educational purposes. Regarding economy, specific (but optional) objects of this invention are:

(a) to provide a basic reflector apparatus (first and/or second main embodiment) made from a plurality of (generally four or more) sheets of thin, high-strength, high-elastic-modulus (preferably), commercially available material(s), plus the

necessary valves, using a substantially flat pattern fabrication method that greatly simplifies manufacturing, tooling, and processing, thereby reducing fabrication cost;

(b) to provide a basic reflector apparatus (second embodiment), which can be fabricated from as few as two thin sheets of high-strength, commercially available material(s), plus the necessary valves, using simple, well-established manufacturing processes; and/or

(c) to provide a modular field-deployable apparatus, wherein one or more of its modules (or components thereof) are sized to substantially match (i.e., have the same size as) other modules (or components thereof), so as to reduce fabrication cost by minimizing the number of different elements that need to be produced (but also to enhance versatility and facilitate repair).

A seventh main object of the invention is to provide a portable multifunctional apparatus that is optionally highly drop tolerant, otherwise damage tolerant, and easy to repair in the event of damage. Regarding damage tolerance and reparability, specific (but optional) objects of this invention are:

(a) to provide an apparatus having one or more redundant reflector chambers such that if one reflector chamber is damaged, the device is still operable;

(b) to provide an apparatus constructed primarily of highly flexible materials (optionally including multi-layered and/or fiber-reinforced composite materials which are puncture-resistant, tear-resistant, and/or abrasion resistant) such that the apparatus can be dropped intentionally (e.g., air dropped), dropped unintentionally (i.e., accidentally), and/or otherwise be subjected to harsh operating conditions yet sustain no appreciable damage; and/or

(c) to provide an apparatus having integral quick-repair materials (e.g., self-adhesive patches and the like).

An eighth main object of the invention is to provide a portable multifunctional apparatus that is highly environmentally friendly by virtue of the fact that the apparatus generally requires no fuel to operate. Instead, the instant invention typically relies solely on radiating solar energy when used for heating, cooking, and the like, thereby minimizing air, water, and ground pollution. This is in stark contrast to other common portable cooking and heating equipment, which generally rely on the combustion of hydrocarbon fuels and, thus, inherently cause pollution through both combustion processes and unintentional fuel releases (e.g., spills, leaks, vapor releases, and the like).

It is a further object of the invention to provide improved elements and arrangements thereof for the purposes described which is inexpensive, dependable, and fully effective in accomplishing its intended purposes.

These and other objects of the present invention will become readily apparent upon further review of the following specification and drawing. However, it is once again emphasized that any particular embodiment or manifestation of the present invention need not perform all such functions or otherwise meet all such objects of the present invention as noted herein, thus prompting the use of the term "optional" and/or "optionally" when referring to the various objects of the invention in several of the preceding paragraphs. Specifically, any particular embodiment of the present invention can be configured to perform and/or meet only a limited number (or subset) of these functions and/or objects without departing from the basic nature of the invention.

BREIF DESCRIPTION OF FIGURES

FIGS. **1A-C** are, respectively, a schematic perspective view, a schematic side elevation cross-sectional view, and an exploded cross-sectional view of a typical modular, inflatable, multi-

function, field-deployable apparatus.

FIGS. **2A-B** are, respectively, a schematic top plan view and a schematic side-elevation view of the basic inflatable reflector apparatus in a currently preferred first embodiment configuration.

FIGS. **2C-D** are a schematic top plan view and a schematic side elevational view of the basic inflatable reflector apparatus showing various optional attachment means for attaching other modules, for connecting other accessory elements, and/or for securing the apparatus as exemplary of the various attachment means which also may be included in the other modules.

FIGS. **3A-3B** are schematic cross-sectional views of the basic first embodiment reflector apparatus being used to concentrate and project, respectively, radiant electromagnetic energy with its reflector chamber deployed in sub-ambient mode.

FIGS. **3C-F** are schematic cross-sectional views of the basic first embodiment reflector apparatus being used to manipulate radiant electromagnetic energy with its reflector chamber deployed in sub-ambient mode (FIG. **3C**) and, alternatively, in super-ambient mode (FIGS. **3D-G**).

FIG. **4A** is a schematic side-elevation view of the basic inflatable reflector apparatus in a second embodiment configuration.

FIGS. **4B-C** are schematic side-elevational views of the basic inflatable reflector apparatus in a second embodiment configuration illustrating the operation of various preferred and alternate reflector chamber configurations.

FIGS. **5A-C** are, respectively, a schematic perspective view, a schematic diametrical cross-sectional view, and a schematic partial cross-sectional view of a modified basic first embodiment reflector apparatus having a removably attached central pressure-deformable membrane.

FIGS. **6A-B** are, respectively, schematic diametric cross-sectional views of alternate first and second embodiment reflector apparatuses having a removably attached reflector chamber.

FIGS. **6C-D** are partial schematic diametric cross-sectional views of a typical attachment means for securing a removably attachable reflector chamber to the toroid.

FIGS. **7A-B** are schematic diametric cross-sectional views of alternate basic first embodiment reflector apparatuses having detuned (i.e., non-parabolic) reflective membranes which are pre-formed, respectively, into spherical and non-spherical surfaces-of-revolution.

FIGS. **8A-B** are, respectively, a schematic top plan view and a schematic diametric cross-sectional view of an alternate basic first embodiment reflector apparatus having a detuned reflective membrane pre-formed into the shape of a radially undulating (or radially stepped) surface of revolution.

FIGS. **9A-D** are schematic top plan views and schematic diametric cross-sectional views of alternate basic first embodiment reflector apparatuses having a detuned reflective membrane pre-formed into the shape of a circumferentially undulating or scalloped surface.

FIGS. **10A-B** are a schematic top plan view and schematic diametric cross-sectional view of an alternate basic first embodiment reflector apparatus having a detuned reflective membrane comprising a plurality (e.g., twelve) of pre-formed, wedge-shaped dimples optionally supported by an underlying radial support grid (e.g., a plurality of radial cords, wires, cables, or the like).

FIGS. **11A-H** are several schematic top plan views and a schematic diametric cross-sectional view of alternate basic first embodiment reflector apparatuses having a detuned reflective membrane comprising a plurality of pre-formed dimples in substantially hexagonal, circular, annular, or rectangular arrays, optionally supported by an underlying support grid.

FIGS. **12A-D** are schematic top plan views and schematic diametric cross-sectional views of alternate basic first embodiment reflector apparatuses having a detuned reflective membrane comprising a plurality of generally wedge-shaped

facets.

FIGS. **13A-D** are schematic top plan views and schematic diametric cross-sectional views of alternate basic first embodiment reflector apparatuses having a detuned composite reflective membrane comprising a plurality of conical facets.

FIGS. **14A-F** are several schematic top plan views and a schematic diametric cross-sectional view of alternate basic first embodiment reflector apparatuses having a detuned composite reflective membrane comprising a plurality of substantially planar facets in substantially circular, annular, or triangular arrays.

FIGS. **15A-B** are a schematic top plan view and a schematic diametric cross-sectional view of an alternate basic first embodiment reflector apparatus having a detuned faceted reflective membrane which is alternately deployed via a plurality of internal ribs or sheets bonded to an opposing membrane.

FIGS. **16A-B** are a schematic top plan view and a schematic diametric cross-sectional view of an alternate basic first embodiment reflector apparatus having a detuned reflective membrane, wherein a central inflatable pressure envelope is disposed between the upper and lower pressure-deformable membranes to mildly distort the reflective membrane.

FIGS. **17A-B** are a schematic top plan view and a schematic diametric cross-sectional view of an alternate basic first embodiment reflector apparatus having a dual-focal-point, detuned reflective membrane resulting in a device having two useable focal points.

FIG. **18** is a schematic cross-sectional view of an alternate modular inflatable multi-function apparatus comprising a reflective membrane integrated with a low-inflation-volume combination spherical support and focal point support.

FIGS. **19A-D** are schematic perspective views illustrating various alternate inflatable safety cages (e.g., truss-like safety shields with optional safety nets).

FIGS. **20A-B** are schematic perspective views illustrating various alternate combination/dual-use safety cages and device

supports.

FIGS. **21A-D** are a schematic perspective view and three schematic cross-sectional views illustrating various alternate collapsible combination safety cage and device supports shown supporting removable reflector chambers.

FIGS. **22A-G** are schematic perspective views illustrating various alternate cable-stayed focal point supports.

FIGS. **23A-B** are schematic cross-sectional views illustrating the use of a waveguide with a super-ambient-pressurized first embodiment basic reflector apparatus.

FIGS. **24A-D** are schematic cross-sectional views illustrating the use of a basic first embodiment reflector apparatus as a fluid pump.

FIGS. **25A-B** are schematic perspective views illustrating the use of additional accessory membranes for both enhanced water collection and use as a shelter.

FIG. **26** is a schematic side elevational view of a modified first embodiment reflector apparatus further including optional accessory elements, such as a peripheral gutter, for facilitating the collection and storage of water.

FIG. **27** is a schematic perspective view of a modified first embodiment reflector apparatus configured as a portable sealed work chamber.

FIGS. **28A-B** are schematic perspective views of a modified first embodiment reflector apparatus further including self-supporting single-axis and dual-axis means for tracking the sun.

FIGS. **29A-C** are schematic perspective views of a modified first embodiment reflector apparatus further including suspended single-axis and dual-axis means for tracking the sun.

FIGS. **30A-D** are schematic perspective views of typical, substantially polymeric, multi-layer, composite materials from which the apparatus can be constructed.

DETAILED DESCRIPTION

FIGS. 1A-C: Modular Inflatable Multifunction Apparatus

Figure **1A** depicts a typical modular, inflatable, multifunction, field-deployable apparatus **600** comprising as its primary functional element a basic inflatable multifunction reflector apparatus **610** in a preferred first embodiment configuration, which is supported on its lower side by a removably attached inflatable spherical support **612** movably couched within a separate inflatable toroidal ring **614**, and which supports on its upper side a removably attached inflatable safety shield **616** or cage that further supports a removably attached cable-stayed support for holding various materials and/or accessory elements in proximity to the focal point of the basic reflector apparatus **610**.

In addition to the safety shield, two other safety means are provided for protecting the user from accidental exposure to potentially dangerous, high concentrations of electromagnetic energy at or near the focal point. First, a removably attached inflatable protective safety cover **620** is shown attached to the upper potion of the safety cage in a deployed (inflated) condition. The protective safety cover can be quickly deployed to either attenuate the amount of electromagnetic energy striking the reflector when the apparatus is being used, or to fully block such electromagnetic radiation when the apparatus is not in use. Second, a protective safety net or mesh (not shown) is attached to the upper portion of the safety shield to restrict non-deliberate physical access to the focal point. Note that the safety net also can be used to provide a convenient support for a partially or fully deployed safety cover, and to structurally stabilize or reinforce the upper end of the safety shield.

Additionally, safety is further enhanced by a plurality of stabilizing cables or lines (not shown), which connect the movable upper portion of the modular apparatus to the surface (e.g., ground) upon which the lower support ring **614** of the apparatus **600** is resting.

Regarding physical construction, briefly note that each module of the apparatus typically is principally constructed

from one or more thin flexible (e.g., pressure-deformable) membranes, one or more lightweight inflatable structures, and/or other flexible structural elements, such as cables, lines, nets, and the like. In addition, each of the inflatable and/or otherwise pressure-deployable modules includes one or more inflation or pressure adjusting means such as a simple plug-type valve (not shown); however, a variety of other well-known inflation or pressure adjusting means may be employed including, for example, manual or automatic pumps, pressurized gas canisters, and the like. Further, to enable the various modules of the modular apparatus to operate as a unit, each module typically includes one or more attachment means (not shown) for attaching the module to other modules, for attaching accessory elements, and/or for securing and stabilizing the apparatus as noted above.

Figure **1B** depicts the modular field-deployable apparatus **600** shown in cross-section concentrating radiant electromagnetic rays **28** (e.g., solar radiation), to heat an energy-absorbing accessory element (not shown), such as a pot, kettle, oven, and the like, suspended in proximity to the focal point **26** via a cable-stayed support **618**. Note that the movable upper portion of the modular apparatus is positioned or couched within the lower support ring **614** to substantially align the focal axis **30** of the basic reflector module **610** with the incoming solar radiation **28**. The safety cover **620** is shown retracted and secured with ties (not shown) (or other attachment means); however, note that the safety cover can be partially deployed, thereby providing an adjustable means for attenuating (i.e., reducing) the amount of concentrated radiant energy impinging upon the element held in proximity to the focal point.

Figure **1C** depicts an exploded cross-sectional view of the modular field-deployable apparatus **600** illustrating in greater clarity its primary modules and their basic physical constructions. Such modular construction allows the apparatus to be readily reconfigured by the user in the field to perform other user-selected functions, as will be shown hereinbelow. Further, such modular construction enhances safety by providing

redundant structures, thereby effectively mitigating the risk of catastrophic collapse of the apparatus.

It should be noted that each of the primary modules of apparatus **600** may optionally comprise a plurality of user-selected, user-detachable sub-modules. For example, as shown hereinbelow, the basic reflector apparatus **610** may alternatively have one or more removable central membranes and/or a removable reflector chamber to increase versatility of the basic reflector apparatus **610** and/or modular apparatus **600**. As another example, the inflatable safety cage module **616** is shown as having a plurality (e.g., four) of removably attached, individually inflated, toroidal rings. This multi-ring configuration also promotes versatility in that the rings can be separated and/or alternately combined with other elements of the apparatus to serve other functions, for example, use as water flotation devices. Note that the use of multiple, separately inflated rings for the safety shield also provides an effective means for mitigating the risk of rapid catastrophic collapse.

It should be further noted that the various modules and/or components thereof (e.g., sub-modules) are shown preferably sized, where possible, to substantially match the size of one or more other modules and/or components of the present apparatus, both to reduce fabrication cost, and to permit similarly sized modules or components to be easily interchanged to increase versatility and/or facilitate maintenance.

The invention also contemplates that one or more of the primary modules of the overall modular apparatus may be integrally attached and, optionally, simultaneously inflated by providing interconnecting gas ports between the integrally attached modules. Although such integration and interconnection may reduce structural redundancy, safety may nonetheless be enhanced, for example, by causing the safety shield to be deployed simultaneously with the reflector apparatus. The invention further contemplates various alternate configurations for each of its primary modules, several examples of which will be shown hereinbelow.

Figures 2A-D Description of the Basic Inflatable Reflector Apparatus - First Embodiment

FIGS. **2A** and **2B** depict a currently preferred first embodiment configuration of the basic inflatable reflector apparatus **610**, which is illustrated as an inflated toroid or ring support element **12** having a circular cross-section and supporting an upper frontal reflective membrane **14** and a lower transparent reflective membrane **17**. The ring support element, as shown in FIGS. **2A-B**, defines a vacant center. The two central reflective membranes **14, 17** in conjunction with the inner portion of the toroidal ring support element **12** provide or define a central reflector chamber (i.e., pressure envelope) **20** with a double parabolic, concave-concave configuration when inflated to a sub-ambient pressure, i.e., deployed in sub-ambient mode. The membranes **14, 17** each have a centered inflation valve **18** as an example of a pressure-adjusting or inflation means for inflating the reflector chamber **20.** (Note that the valve **18** disposed in the transparent membrane **17** has been omitted from the figure.) The inflatable toroidal ring support element **12** also has a valve **18** as an example of an inflation means for inflating the ring support element to form a rigid ring. It should be noted that by utilizing the inner portion of the ring support element as an integral part of the reflector chamber, the first embodiment device **610** can be manufactured very economically from a minimum number of pieces.

The toroidal ring support element **12** is fabricated from two sheets, which are substantially flat and annular prior to inflation, and which are adhesively or thermally bonded to each other along continuous seams **22** at their inner and outer periphery to form a toroid upon inflation, as one example of forming the toroid. The two sheets comprising the toroid **12** are made of a high-strain-capable material, i.e., a material having high strength and low elastic modulus, such as vinyl, which is necessary for allowing the inner potion of a toroid fabricated from flat annular sheets to strain (i.e., stretch) sufficiently so as not to impede full inflation of the toroidal ring support

element **12**.

The central pressure-deformable membranes **14, 17** are made from thin circular sheets of high-strength, flexible material such as nylon or Mylar®, a polyethylene terephthalate plastic composition. Reflective surface **24** is provided by preferably coating the outer side of the membrane **14** with vapor deposited aluminum and the like reflective material. The reflective membrane **14** is thermally or otherwise pre-formed during fabrication into the shape of a paraboloid to provide a short, fixed focal length for safety purposes and to reduce the differential pressure required to fully deform and smooth the reflective membrane **14**, thus facilitating deployment as well as reducing the loads imposed on the support ring by the reflective membrane (mechanical loads) and the reflector chamber (pressure loads). The transparent membrane **17** optionally may also be pre-formed to reduce the load it imposes on the support ring. Seams **22** are provided for adhesively or thermally bonding the periphery of the central membranes **14, 17** to the toroid **12** at or near what will become circular lines of tangency between the central membranes **14, 17** and the toroidal ring support element **12** upon inflation.

Numerous alternate toroid configurations can be incorporated (i.e., substituted) into the basic first embodiment device as described above. FIG. **2A** shows that the toroidal ring support element **12** has a circular planform; however, it is noted that the invention can be practiced using other types of supports including those having hexagonal, square, rectangular, elliptical, and other planforms. (Note that planforms having at least one substantially linear peripheral edge may prove useful for orienting and/or stabilizing the apparatus.) Furthermore, the simple two-sheet construction of the toroid as described above may be replaced with various alternate toroidal ring support elements offering greater performance and stability, but generally at the expense of somewhat greater complexity. For example, the toroid optionally may be fabricated from a plurality (e.g., generally four or more) flat annular sheets of high modulus material, such as described in our previous (cross-referenced) applications, which also describe several other

alternate configurations. Additionally, it should be noted that the invention is not intended to be limited to the specific materials and/or configurations as specified above for the toroid. Depending on the configuration, the toroid can be made from any suitably flexible material, including various other substantially polymeric materials, including monolithic, layered, and/or fiber-reinforced composite material.

Similarly, numerous alternate central pressure-deformable membrane configurations can be incorporated (i.e., substituted) into the basic first embodiment device as described above. For example, the invention can be practiced using a planar (i.e., non-pre-formed) pressure-deformable reflective membrane to yield a device capable of providing a variable focal length as a function of the differential pressure imposed across the reflective membrane **14**. Furthermore, the use of pre-formed, non-parabolic reflective membranes (e.g., reflective membranes having surfaces which are spherical, undulating, dimpled, faceted, or which comprise a series of conic sections, and the like) is contemplated to limit the maximum degree of concentration to further enhance safety and/or to provide more uniform heating. The invention can also employ a redundant reflective membrane such as described in our previous cross-referenced applications (e.g., the transparent membrane can be replaced with a reflective membrane to provide a second reflector having optionally similar or significantly different optical properties, such as focal length). It should be noted that the invention is not intended to be limited to the specific materials and/or configurations as specified above for the central pressure-deformable membranes. Similar to the toroid, depending on the configuration, the central membranes can also be made from any suitably flexible material, for example, other substantially polymeric materials, including monolithic, layered, and/or fiber-reinforced composite materials. Additionally, the reflective surface can be provided by a plastic reflective membrane, which alternatively has reflective particles homogeneously incorporated, or which contains an integral conductive wire or mesh, all of which tend to selectively reflect or filter the impinging radiation. Also,

the device may optionally incorporate membranes having other arbitrary but useful optical properties such as selective transparency, translucency, opacity, color, texture, and/or polarization for practical and/or artistic applications.

Regarding valves, note that the pre-formed pressure-deployable central membranes are shown (in FIGS. **1B** and **1C**) as having a funnel-shaped region surrounding the centered inflation valve to facilitate fluid collection. Membranous valves may also be employed, including those having self-sealing means such as used in toy balloons, or Ziploc® type tongue-and-groove sealing means.

To fully deploy the basic first embodiment device **610** in sub-ambient mode as shown in FIGS. **2A** and **2B**, the device, which is typically compactly folded for portage and storage, is first unfolded to gain access to the inflation valves **18**. Subsequently, the toroidal ring support element **12** is inflated to a super-ambient pressure to rigidize the ring support element **12** as is necessary to properly support and tension the central membranes **14, 17**. The reflector chamber **20** is then inflated to a sub-ambient pressure (as is required for most applications) to deform and smooth the reflective membrane **14** into a concave, substantially parabolic reflector. Finally, the focal axis of the parabolic reflective membrane is appropriately oriented toward the energy source and/or target, as required for a particular application or mode of operation. As previously noted, the first main embodiment device **610** can also be deployed in super-ambient mode as shown later in this document.

Figure **2C** depicts a currently preferred first embodiment configuration of the basic inflatable multi-function reflector apparatus **610** further including various optional accessory attachment means for attaching other modules, for connecting other accessory elements, and/or for securing and stabilizing the apparatus. A pair of handles **32** is positioned diametrically on the sides of the toroid **12**. An apertured tab **34** is provided on a side equidistantly between the handles **32** for hanging up when in storage or the like. A pair of tying or hanging straps **36** is attached on either side of the apertured tab **34**. A

storage pouch **38** is provided for storing the deflated and folded apparatus **610**. A pair of bottom pouches **40** is provided for filling with dense material to stabilize an upright apparatus **610**. It should be noted that these appendages can be incorporated into the device in any useful quantity, location, and combination thereof. It should also be noted that each of these appendages is highly amenable to fabrication from thin membrane materials to minimize size and weight to facilitate portage and storage, and that each can be fabricated fully or in part from extensions of the central membranes **14**, **17** and/or the membranes comprising the toroidal support element **12** to facilitate manufacturing.

FIG. **2D** depicts other various optional attachment devices which are generally rigid or semi-rigid, but which are preferably collapsible to facilitate portage and storage. Examples include a clevis, shackle, clip or bracket **54** for attaching various accessory elements including, for example, a support rod **56** or a line. Hook-and-loop fastening patches **58** and a mounting stud **60** are also provided for attaching various accessory elements. A centered socket **62** is shown in the upper frontal reflective membrane **14** for supporting other accessory elements including, for example, an antenna **64**.

It should be noted that any of these attachment devices can be incorporated into the basic reflector apparatus **610** (or any other module, sub-module, and/or accessory elements of the present invention, including any alternate embodiments or configurations thereof) in any useful quantity, location, and combination thereof. Further, one or more of these attachment means may be combined or otherwise integrated with other various features of the present invention to facilitate manufacture or for other purposes. For example, an inflation valve **18** may be combined with a mounting bracket **54**, hook-and-loop fastening patches **58**, a socket **62**, or the like.

Figures 3A-G Operation of the Basic Inflatable Reflector Apparatus - First Embodiment

FIG. **3A** depicts the first main embodiment device **610**

deployed in sub-ambient mode as an electromagnetic radiant ray concentrator having the focal axis **30** of the pre-formed parabolic reflective membrane **14** oriented toward the sun (not shown). The radiant solar rays **28** are reflected by the pre-formed parabolic reflective membrane **14** to focus on an energy-absorbing object (not shown) placed at the focal point **26.**

Regarding the instant device's ability to capture and concentrate electromagnetic radiation, it should first be noted that a device deployed in sub-ambient mode allows the electromagnetic rays to travel unobstructed to and from the reflector, thus providing superior capture efficiency relative to much of the prior art as well as the second main embodiment of the instant invention (capture efficiency is defined herein as the portion of the incoming radiant energy that is delivered to the focal point and local surrounding area). As an example, when operated in sub-ambient mode as a terrestrially-based solar concentrator as shown in FIG. **3A**, the first main embodiment device has an effective capture efficiency exceeding 90%, which is limited only by the reflective efficiency of the membrane and the transmission and dispersion characteristics of the surrounding atmosphere. Second, although a reflective parabolic surface is the ideal geometry for reflecting all incoming parallel radiant rays to the focal point and, thus, producing extremely high theoretical concentrations of energy, the ability of the instant device to concentrate energy is limited by several factors including, but not limited to, the geometric precision of the reflective membrane and, hence, its supporting toroidal ring support element, the capture efficiency of the device as noted above, the apparent finite angular diameter of the source (e.g., the sun), and the wavelength of the radiation relative to the diameter of the reflector. Despite these and other limiting factors, a precisely constructed first embodiment device used as a terrestrially-based solar concentrator has the ability to concentrate sunlight by factors in excess of 10,000.

Regarding safety, as one consequence of having a pre-formed reflective membrane **14**, the device has a fixed focal length, i.e., the focal point is located at a substantially fixed distance from the reflective membrane along the focal axis of

reflector **14**. This fixed focal length greatly enhances safety by allowing the user to maintain greater control of the location of any potentially dangerous high concentrations of electromagnetic radiation at the focal point. A second consequence of employing thermally or otherwise pre-formed reflective membranes is that pre-forming allows the reflectors to achieve significantly shorter focal lengths than is practical using non-pre-formed, planar membranes due to the limited ability of planar membranes to elastically deform. The very short focal lengths achieved by such deeply pre-formed reflective membranes further enhance safety by providing the user with even greater control over the location of the concentrated electromagnetic radiation.

FIG. **3B** depicts a first main embodiment device **610** deployed in sub-ambient mode as a radiant ray projector with the same reflector structure **20** as shown in FIG. **3A**, but projecting a collimated beam of the electromagnetic rays from a non-collimated light source (not shown) such as a light bulb, lamp, or candle placed at the focal point **26** to a distant object (not shown). It should be noted that the selection of the concentrating or projecting mode depends on the position of the light or other electromagnetic source relative to the focal point of the device.

It should be further noted that the focal axis of the pre-formed parabolic reflective membrane **14**, as depicted in FIGS. **3A** and **3B**, is coincident with the axis-of-revolution of the toroidal support element **12**, thereby causing the focal point of the device to be aligned with the axis-of-revolution of the toroid and, thus, to be located directly above the center of the reflective membrane. However, the reflective membrane **14** may be pre-formed and/or attached to the toroid support element **12** in such a manner that the focal point of the device **610** is located off the axis-of-revolution of the support ring **12**. Note that such "off-axis" reflectors can facilitate orientating the device relative to the energy source and/or target for certain applications.

FIG. **3C** depicts the apparatus **610** in sub-ambient mode. In

contrast, FIG. **3D** depicts the basic first embodiment reflector apparatus **610** being used to concentrate radiant electromagnetic energy **28** with its reflector chamber **20** alternatively deployed in super-ambient mode (i.e., the reflector chamber is inflated to a super-ambient pressure to outwardly deploy the reflective membrane). Note that central membranes **14, 17** are pre-formed such that the focal point is located substantially at the surface of the transparent membrane **17** of the super-ambient pressurized reflector chamber **20,** thereby allowing the transparent membrane **17** to directly support a suitable electromagnetic accessory device (not shown) in proximity to the focal point.

FIG. **3E** depicts a first main embodiment device **610** deployed in super-ambient mode as a radiant ray diffuser with the same reflector structure **20** as shown in FIG. **3D,** but used alternatively as a convex mirror, such as for expanding the user's field of view for surveillance or safety. More specifically, the apparatus can serve as an economical field-deployable convex mirror, which can be used, for example, to allow a vehicle operator to see around a blind corner.

FIG. **3F** depicts a modified basic first embodiment reflector apparatus **610** being used to concentrate radiant electromagnetic energy with its reflector chamber **20** deployed in super-ambient mode, wherein the central membranes **14, 17** are pre-deformed such that the focal point **26** is located *outside* the super-ambient pressurized reflector chamber **20.**

Figure **3G** depicts a modified basic first embodiment reflector apparatus **610** being used to concentrate radiant electromagnetic energy with its reflector chamber **20** deployed in super-ambient mode, wherein the central membranes **14, 17** are pre-deformed such that the focal point **26** is located *within* the super-ambient pressurized reflector chamber **20.**

Figures 4A-C Description and Operation of the Basic Inflatable Reflector Apparatus -- Second Embodiment

In FIG. **4A**, the second main embodiment device **386** is illustrated as an inflated toroid or ring support element **400** supporting an upper transparent membrane **388** and a lower reflective membrane **390**. The transparent membrane **388** and reflective membrane **390** provide a central reflector chamber (i.e., pressure envelope) **392** with a double parabolic convex-convex lens configuration when inflated to a super-ambient pressure. The transparent membrane **388** has a centered inflation valve **18** for inflating the reflector chamber **392**; however, it is noted that the inflation valve **18** may alternatively be located at any other useful location such as in the reflective membrane **390**. The inflatable toroidal support element **400** also has a valve **18** for inflation to form a rigid ring. Two valves are shown for separate inflation of the ring support **400** and the reflector chamber **392**; however, it is noted that the two pressure envelopes (the toroid **400** and the reflector chamber **392**) can be interconnected, thereby allowing both super-ambient pressure envelopes to be inflated with a single valve **18**.

The toroidal support element **400** is fabricated from two thin sheets **401** of material, each of which is fully pre-formed into the shape of a half toroid and adhesively or thermally bonded to each other along continuous seams **22** at their inner and outer periphery, as one example of forming the toroid. The two sheets **401** comprising the toroid **400** are made of a flexible, high-strength material capable of being thermally or otherwise pre-formed, such as vinyl, nylon, and the like.

The transparent membrane **388** is made from a thin circular sheet of transparent, high-strength, flexible material such as Mylar® or Nylon. The reflective membrane **390** is also made from a thin circular sheet of high-strength, flexible material such as Mylar® or Nylon; however, a reflective surface **24** is provided by coating the inner side (preferred, but not necessary if the uncoated membrane material is otherwise transparent) of the membrane **390** with vapor deposited aluminum and the like reflective material. The reflective membrane **390** is pre-formed during fabrication substantially into the shape of a paraboloid to provide a substantially fixed, short focal length for safety purposes, and to reduce the differential pressure required to

fully deform and smooth the reflective membranes **390** to facilitate deployment. The transparent membrane **388** is optionally also pre-formed, primarily to reduce loads imparted on the support ring; however, the transparent membrane **388** also can be pre-formed for other purposes, such as to facilitate supporting an accessory element in close proximity to the focal point as will be shown below. However, the transparent membrane need not be pre-formed (or it can be pre-formed to a different extent than the reflective membrane), thus yielding an asymmetrical reflector chamber. Seams **22** are shown for adhesively or thermally bonding the outer periphery of the reflective and transparent membranes **388, 390** to the inner edge of the toroid **400**. This basic, four-sheet, fully pre-formed construction represents a first species of the second main embodiment device **386**.

Similar to the first embodiment, it should be noted that several alternate toroid, central membrane, and valve configurations can be incorporated (i.e., substituted) into the basic second embodiment device as described above. In addition to having alternate plan forms, the simple two-sheet toroidal support element **400** as described above may be replaced with alternate support rings offering greater performance and/or stability, but generally at the expense of somewhat greater complexity. However, such alternate support ring configurations for the second embodiment are limited to those particular configurations wherein the portion of the support ring to which the reflector chamber is bonded does not move appreciably in the radial direction upon inflation. Otherwise, either the reflector chamber will generally restrict proper inflation of the toroid resulting in a buckled ring structure, or the inflated ring will not properly tension the perimeter of the reflective membrane. Numerous alternate membrane configurations can be incorporated (i.e., substituted) into the basic second embodiment device as described above including membranes having any of the alternate shapes, functional characteristics, optical properties, constructions, and materials as noted for the first embodiment. The many optional valves or other inflation means available for the first embodiment are also available for the

second embodiment. Note that our previous (cross-referenced) applications describe several useful alternate configurations for the toroid, membranes, valves, and other elements, all of which are generally applicable to the present invention.

FIG. **4B** depicts the second main embodiment **386** in an electromagnetic radiant ray concentrating mode having the transparent membrane **388** facing the sun (not shown). The radiant solar rays **28** are illustrated as passing through the transparent membrane **388** to the reflective membrane **390,** which then reflects the rays back through the transparent membrane **388** to focus on an energy-absorbing object **394** placed at the focal point of the device **386.** Although the figure shows the focal point to be outside of the reflector chamber, it should be noted that the reflective and transparent membranes can each be pre-formed or otherwise deformed to any predetermined shape or extent (e.g., deeply pre-formed, moderately pre-formed, non-pre-formed, etc.) such that the focal point alternatively is located inside the reflective chamber, or at the surface of the transparent membrane, such as shown in FIG. **4C**. However, the reader is cautioned that the latter case should be restricted to low-power (e.g., radio frequency) applications to prevent the possibility of thermally or otherwise damaging the transparent membrane and/or any integral or removable elements attached to the surface of the transparent membrane at or near the focal point. Additionally, by pre-forming the reflective membrane and transparent membrane to different extents, an asymmetrical reflector chamber is provided. For example, an apparatus may have a deeply pre-formed reflective membrane and a slightly pre-formed transparent membrane to yield an asymmetrical reflector chamber having a very short focal length. In contrast, an apparatus may have a slightly pre-formed reflective membrane and a deeply pre-formed transparent membrane to yield an asymmetrical reflector chamber having a relatively long focal length.

The basic second embodiment reflector apparatus may have an alternate configuration, wherein the attachment means for the central reflector chamber is offset or displaced from the inner periphery of the toroidal support ring to accommodate a larger

reflective membrane.

Additionally, the basic second embodiment reflector apparatus may have an alternate configuration, wherein the attachment means for the central membranes of the reflector chamber are offset or displaced in opposite directions from the inner periphery of the toroidal support ring to accommodate a still larger reflective membrane. Note that this configuration is similar to that of the first embodiment except that the transparent membrane is highly pre-deformed to an extent that the apparatus cannot operate in sub-ambient mode (i.e., the central membranes would experience significant interference).

Figure 5A-C Removable Central Membranes

FIGS. **5A-C** depict a modified first embodiment basic reflector apparatus having a removable upper central membrane, which is removably attached via a quick attachment and sealing means, such as a tongue-and-groove fastening mechanism, to the toroid. FIG. **5C** shows the removable membrane having an affixed integrated multi-tongue element inserted into a multi-groove element affixed to the toroid. The use of multiple tongues and grooves provides structural and sealing redundancy; however, a single tongue-and-grove can be used to promote economy. The lower central membrane optionally may also be removably attached by such means. Note that such means for removably attaching the central membranes allows the user to remove or replace the membranes to enable the apparatus to perform other functions, or to replace a membrane in the event of damage. To facilitate replacement, the removable central membranes and the toroid can optionally further include complementary visual and/or mechanical alignment features (not shown) such as indicia, positioning tabs, studs, alignment holes, snaps, and the like.

Figures 6A-D Removable Reflector Chamber

FIG. **6A** depicts an alternate basic first embodiment

reflector apparatus having a removably attached sub-ambient/super-ambient pressurizable reflector chamber.

FIG. **6B** depicts an alternate basic second embodiment reflector apparatus having a removably attached super-ambient-pressurizable reflector chamber.

FIG. **6C** depicts a typical hook or clip-type attachment means for quickly securing a removably attachable reflector chamber of the first embodiment type to the toroidal support ring. FIG. **6D** depicts a similar hook or clip-type attachment means for securing a removably attachable reflector chamber of the second embodiment type to the toroidal support ring. It is noted that other common means can be employed to attach such removable reflector chambers including, for example, one or more attachment means similar to those previously shown in FIGS. **2C-D** (e.g., hook-and-loop patches, a plurality of discrete mounting studs with corresponding apertures, and the like).

Figures 7A-17B Alternate Detuned Reflective Membranes

FIG. **7A** depicts an alternate basic first embodiment reflector apparatus having a detuned (i.e., non-parabolic) reflective membrane, (first species, first sub-species) wherein the reflective membrane is pre-formed to have a spherical surface contour. Note that the rays do not converge at a single point, thereby limiting the degree of concentration to enhance safety.

Figure **7B** depicts an alternate basic first embodiment reflector apparatus having a detuned (i.e., non-parabolic) reflective membrane (first species, second sub-species), wherein the reflective membrane is pre-formed to have a surface contour comprising a surface-of-revolution of non-constant radius.

FIGS. **8A** and **8B** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane (first species, third sub-species), wherein the reflective membrane is pre-formed into the shape of a radially undulating (or radially stepped) surface of revolution. Again, FIG. **8B** shows that the rays do not converge at a single point.

FIGS. **9A** and **9B** depict an alternate basic first embodiment

reflector apparatus having a detuned reflective membrane (second species, first sub-species), wherein the reflective membrane is pre-formed into a circumferentially undulating or scalloped shape having an even number (e.g., two) of circumferential peaks and troughs. Similarly, FIGS. **9C** and **9D** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane (second species, second sub-species), wherein the reflective membrane is pre-formed into a circumferentially undulating or scalloped shape having an odd number (e.g., three) of circumferential peaks and troughs. In FIGS. **9B** and **9D**, the electromagnetic rays shown dashed represent rays in the plane of the cross-section, and the dotted lines represent rays out of the plane of the cross-section. Note that the reflector of FIG. **9B** tends to produce a vertically dispersed ray concentration pattern, whereas the reflector of FIG. **9D** tends to produce a horizontally dispersed or annular ray concentration pattern. Note that any number of peaks and troughs may be incorporated into such circumferentially undulating or scalloped membranes.

FIGS. **10A-B** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane (third species, first sub-species), wherein the reflective membrane comprises a plurality (e.g., twelve) of pre-formed, wedge-shaped dimples optionally supported by an underlying radial support grid (e.g., a plurality of radial cords, wires, cables, or the like). FIG. **10B** shows that the electromagnetic rays reflected by each dimple form a diffuse, substantially linear focal locus prior to diffusely converging in proximity to the primary focal axis of the reflector.

FIGS. **11A** and **11B** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane (third species, second sub-species), wherein the reflective membrane incorporates a plurality (e.g., eighteen) of large pre-formed substantially circular and/or elliptical dimples, which are generally arranged in a staggered pattern or array, such as a substantially hexagonal lattice, to maximize packing density, and further optionally includes a plurality (e.g., twelve) of smaller dimples (not shown) disposed around

the larger dimples to further minimize the non-dimpled area of the detuned reflective membrane. An optional underlying mesh may be used to support and/or reinforce the dimpled reflective membrane; however, as will be shown below, a support grid or mesh is required for membranes having dimples which substantially comprise the entire surface of the membrane.

FIGS. **11C-11H** depict various other dimpling patterns for dimpled detuned reflectors. Specifically, FIG. **11C** depicts a dimpling pattern (third species, third sub-species) incorporating a plurality (e.g., eighteen) of pre-formed substantially circular and/or elliptical dimples, which are generally arranged in a staggered concentric circular pattern or array, wherein a plurality of medium-sized dimples (e.g., six) are surrounded by a plurality (e.g., twelve) of alternating smaller and larger dimples to maximize packing density for a given number of substantially circular and/or elliptical dimples. FIG. **11D** depicts a dimpling pattern (third species, fourth sub-species) incorporating a generally staggered array of large and optionally small (not shown) pre-formed substantially circular dimples, which are arranged in such a manner so as to allow the reflective membrane to be reinforced in three directions by a plurality of linear cords, wires, cables, or the like (shown dashed). FIG. **11E** depicts a dimpling pattern (third species, fifth sub-species) incorporating a simple, substantially rectangular array of large and optionally small (not shown) pre-formed circular dimples, which are arranged in such a manner so as to allow the reflective membrane to be reinforced in two directions by a plurality of linear cords, wires, cables, or the like (shown dashed). FIG. **11F** depicts a dimpling pattern (third species, sixth sub-species) incorporating a generally hexagonal array of pre-formed dimples supported by a hexagonal support grid, wherein each dimple substantially comprises the entire area of its associated cell within the hexagonal support grid. FIG. **11G** depicts a dimpling pattern (third species, seventh sub-species) incorporating a generally rectangular array of pre-formed dimples supported by a rectangular support grid, wherein each dimple substantially comprises the entire area of its associated cell within the

rectangular support grid. Similarly, FIG. **11H** depicts a dimpling pattern (third species, eighth sub-species) incorporating a concentric annular array of tapered quadrilateral dimples supported by a tapered quadrilateral support grid, wherein each dimple substantially comprises the entire area of its associated cell within the support grid. It should be noted that dimples of any pre-determined size, quantity, shape, and/or combinations thereof may be employed to tailor the light concentration pattern to a predetermined intensity and distribution, i.e., the invention is not limited to the specific examples shown.

FIGS. **12A-B** depict an alternate basic first embodiment reflector apparatus having a composite detuned reflective membrane (fourth species, first sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane selectively bonded to a pressure-deformable membranous substrate along a plurality (e.g., twelve) of radial lines or seams to provide an equal number of wedge-shaped facets, each of which is curved in the radial direction and substantially flat in the circumferential direction. One or more orifices need to be provided to allow gas (e.g., air) to freely enter or exit the chambers or cavities between the reflective membrane and substrate membrane. Such orifices can be included in and/or around the periphery of the reflective membrane. FIG. **12B** shows that the electromagnetic rays reflected by each facet form a diffuse, substantially linear focal locus (shown dotted) in proximity to the primary focal axis of the reflector.

Similarly, FIGS. **12C-D** depict an alternate basic first embodiment reflector apparatus having a composite detuned reflective membrane (fourth species, second sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate along a combination of radial seams and parallel-to-radial seams to provide a plurality (e.g., twenty-four) of alternating wedge-shaped facets and circumferentially truncated wedge-shaped facets, each of which is curved in the radial direction and substantially flat in the

circumferential direction. FIG. **12D** shows that the electromagnetic rays reflected by each facet form a diffuse, substantially linear focal locus (shown dotted) in proximity to the primary focal axis of the reflector; however, this pattern produces a more uniform but more highly concentrated pattern of energy than is provided by the faceted reflector of FIG. **12B.**

FIGS. **13A-B** depict an alternate basic first embodiment reflector apparatus having a composite detuned reflective membrane (fifth species, first sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane selectively bonded to a pressure-deformable membranous substrate along a plurality (e.g., five) of equally spaced circumferential lines or seams to provide a plurality (e.g., four) of conical facets of equal radial width, each of which is curved in the circumferential direction and substantially flat in the radial direction. FIG. **13B** shows that the electromagnetic rays reflected by each facet converge in proximity to the primary focal axis of the reflector to provide a substantially spherical pattern of concentrated light.

Similarly, FIGS. **13C-D** depict an alternate basic first embodiment reflector apparatus having a composite detuned reflective membrane (fifth species, second sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate along a plurality (e.g., five) of circumferential lines or seams having progressively reduced radial spacing to provide a plurality (e.g., four) of conical facets of decreasing radial width, each of which is curved in the circumferential direction and substantially flat in the radial direction. FIG. **13D** shows that the electromagnetic rays reflected by each facet converge in proximity to the primary focal axis of the reflector to provide a substantially planar pattern of concentrated light.

FIGS. **14A-B** depict an alternate basic first embodiment reflector apparatus having a composite detuned reflective membrane (sixth species, first sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane selectively bonded to a pressure-

deformable membranous substrate at a plurality of discrete points in an annular pattern or array (i.e., aligned concentric circular arrays) to form a plurality (e.g., ninety-six) of substantially planar quadrilateral facets having constant width in the radial direction. FIG. **14B** shows that the electromagnetic rays reflected by each facet form an associated non-concentrated column of light, all of which converge in proximity to the primary focal axis of the reflector to provide a substantially spherical pattern of concentrated light. It should be noted that this planar faceted configuration forms a substantially spherical pattern of concentrated energy that is more uniform than that provided by the conically faceted reflector of FIG. **13A-B**.

FIGS. **14C-14F** depict various other faceting patterns for faceted detuned composite reflectors. Specifically, FIGS. **14C** depicts a faceted composite detuned reflective membrane (sixth species, second sub-species), wherein the composite reflective membrane comprises a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate at a plurality of discrete points in an annular pattern or array to form a plurality (e.g., ninety-six) of planar quadrilateral facets having decreasing width in the radial direction. Note that this planar faceted configuration forms a substantially planar pattern of concentrated energy similar to that provided by the conically faceted reflector of FIG **13C-D**, but which is significantly more uniform. Similarly, FIG. **14D** depicts a faceted composite detuned reflective membrane (sixth species, third sub-species) comprising a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate at a plurality of discrete points in a staggered pattern of concentric circular arrays to form a plurality (e.g., 168) of planar triangular facets having optionally constant width in the radial direction. FIG. **14E** depicts a faceted composite detuned reflective membrane (sixth species, fourth sub-species) comprising a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate at a plurality of discrete points in a generally triangular pattern or array to form a plurality (e.g., ninety-six) of planar,

substantially equilateral, triangular facets. FIG. **14F** depicts a faceted composite detuned reflective membrane (sixth species, fifth sub-species) comprising a mechanically deformable reflective membrane bonded to a pressure-deformable membranous substrate at a plurality of discrete points in a generally annular pattern or array to form a plurality (e.g., 96) of intermixed planar quadrilateral and triangular facets.

It should be noted that the use of substantially planar facets provides excellent control of the maximum degree to which the light can be concentrated. More specifically, the light concentration factor cannot exceed the number of planar facets. Further, facets of any pre-determined size, quantity, shape, and/or combinations thereof may be employed to tailor the light concentration pattern to a predetermined intensity and distribution, i.e., the invention is not limited to the specific examples shown.

FIGS. **15A** and **15B** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane (seventh species) comprising a mechanically deformable reflective membrane bonded to an opposing membrane via a plurality of internal linear radial ribs and linear (i.e., chorded) circumferential ribs or sheets to form, in an annular pattern, a plurality (e.g., ninety-six) of substantially planar quadrilateral facets having constant width in the radial direction, whereby the reflector can be deployed without imposing a differential pressure across the reflective membrane. However, one or more orifices need to be provided to allow gas (e.g., air) to freely enter or exit the chamber(s) between the reflective membrane and opposing membrane. Such orifices can be included in (and/or around the periphery of) the reflective membrane and/or opposing membrane, and may also be included in the internal ribs to allow interconnection of the compartments within the central chamber. Note that other faceting patterns may be produced, such as any of the preceding faceted patterns described herein, by the judicious use of radial, circumferential, and/or otherwise oriented internal ribs. Additionally, the central reflector chamber of this

configuration may be pressurized to adjust the degree of energy concentration.

FIGS. **16A** and **16B** depict an alternate basic first embodiment reflector apparatus having a detuned reflective membrane, (eighth species) wherein a secondary central inflatable pressure envelope is disposed between the upper and lower pressure-deformable membranes (i.e., centered within the reflector chamber) to mildly distort the reflective membrane to provide an annular focus. This configuration enables the concentration and distribution of light to be adjusted by varying the pressure within the secondary central pressure envelope.

FIGS. **17A** and **17B** depict an alternate basic first embodiment reflector apparatus having a dual-focal-point, detuned reflective membrane, wherein an underlying tensioned cord, wire, or cable diametrically spanning the toroid distorts the reflective membrane to provide two discrete detuned focal points, whereby the apparatus can simultaneously accommodate two distinct accessory elements (not shown), one at each focal point.

Operation as a Broad-Spectrum Electromagnetic Energy Concentrator:

The modular multi-function apparatus can be used to concentrate solar energy to heat or cook materials contained in a vessel supported by the cable-stayed focal point support in proximity to the focal point.

Alternatively, the modular multi-function apparatus can be used to concentrate solar energy to distill liquids contained in a distillation apparatus supported by the cable-stayed focal point support in proximity to the focal point.

Further, the modular multi-function apparatus can be used to provide thermal energy by concentrating sunlight onto a heat exchanger supported by the cable-stayed focal point support in proximity to the focal point, wherein a liquid effluent is cyclically heated and piped via conduits to and from an

insulated energy-storage vessel or thermal reservoir.

Additionally, the modular multi-function apparatus can be used to generate electrical power by concentrating sunlight onto a liquid-cooled photo-electric cell supported by the cable-stayed focal point support in proximity to the focal point. Electrical conduits transmit electrical energy to a device requiring electrical power. Note that thermoelectric cells can also be employed for this purpose. Further note that the optional heat exchanger used to cool the photovoltaic cell device can effectively be used to provide heat as noted above.

Operation as a High-Gain Radio-Frequency Antenna:

The modular multi-function apparatus can be used as a high-gain antenna to enable electronic communications between a geo-synchronous satellite and a ground-based communications device, such as a portable computer, by supporting via the cable-stayed focal point support a basic antenna at the focal point of a sub-ambient pressurized reflector chamber. Electrical conduits may be provided for connecting the basic antenna to the ground-based communications device.

Additionally, the modular multi-function apparatus can be used as a high-gain antenna to enhance electronic communications between a distant radio transmission tower and a portable transceiver device, wherein the transparent membrane of a super-ambient pressurized reflector chamber is alternatively used to support a basic antenna in proximity to the focal point. Note that the basic antenna device may be integrally incorporated into the transparent membrane as an integral conductive wire, mesh, or other suitable conductive element. Also note that for this and other applications, the transparent membrane need only be transparent to the particular spectrum of electromagnetic radiation (e.g., RF) being manipulated by the apparatus. Accordingly, the invention contemplates that the transparent membrane can be opaque, translucent, or otherwise disruptive to higher energy spectra, (e.g., broad-spectrum solar energy, visible light, infrared, and the like) to prevent inadvertent damage to the transparent membrane and/or an accessory element

(such as a portable transceiver device, cellular phone, and the like) supported thereon in the event the apparatus inadvertently becomes aligned with a high-energy electromagnetic source, such as the sun.

Alternatively, the modular multi-function apparatus can be used as a high-gain antenna to extend the range of electronic communications between two portable transceiver devices by attaching one of the transceiver devices directly to the spherical support element. This configuration allows the apparatus to be quickly converted between various operational modes, such as between use as a high-gain antenna and use as, for example, a broad-spectrum concentrator.

Further, two electrically interconnected modular multi-function apparatuses located on a mountain can be used as high-gain antenna apparatuses (each similar to those noted above) to relay electronic communications between a low-lying transmission tower and a third modular apparatus located on opposite sides of the mountain. It is noted that a single modular multi-function apparatus may be reconfigured by the user to provide two or more reflector modules (such as by attaching a removable reflector chamber to, for example, the separate toroidal support ring or the rings of the safety shield), thus enabling a single apparatus to serve as a relay station between non-aligned remote stations. However, depending on the element selected to support the auxiliary removable reflector chamber, alternate means for supporting the apparatus may need to be implemented.

Operation as a Visible Spectrum Concentrator and Projector:

The modular multi-function apparatus can be used to project a collimated beam of light for enhancing vision, signaling, and the like, by locating a non-collimated light source at the focal point of a sub-ambient pressurized reflector chamber. Various light sources can be used for this application including, for example, a gas or oil lantern, an electrical lamp, a candle, a torch, a phosphorescent glow stick, and the like. Note that the device can optionally include reflectors, transparent covers, and/or transparent membranes (if used in super-ambient mode)

having various colors to enable the device to project a wider range of signals, or to project colored illumination, such as for artistic purposes.

Additionally, the modular multi-function apparatus can be used to concentrate moonlight from a crescent moon onto an item to be viewed at night, such as a map or compass, optionally held in proximity to the focal point by the transparent membrane of a super-ambient pressurized reflector chamber. Note that other dim or distance sources of light may also be used for this application, such as a distant street lamp, or the glow emanating from a distant city skyline. Also note that the apparatus alternatively can be deployed in sub-ambient mode for this or other applications disclosed herein.

Further, the modular multi-function apparatus can be used in conjunction with an accessory waveguide device to concentrate and transmit concentrated solar or lunar radiation via waveguide to an underwater lamp to provide pan-chromatic illumination for use by a diver. Note that this configuration can also be used to provide illumination for interior, subterranean, and/or other darkened environments, or to energize optical equipment such as, for example, an image projection device, a heated tool, or a surgical device.

Operation as a Support or Shelter:

The modular multi-function apparatus can be used in an upright position as an insulated crib, cradle, or incubator, such as to hold an infant. In addition to the reflective membrane, the invention contemplates that many of the other elements of the apparatus, such as the interior and/or or exterior walls of the safety shield can have a reflective surface to enhance the thermal insulating characteristics of the apparatus. Alternatively, the modular multi-function apparatus can be used in a horizontal position by a person as a seat or chair, and as a shield from the sun, wind, and/or inclement weather. Further, the modular multi-function apparatus can be used in an inverted position as a shelter to protect a person from inclement weather or other environmental elements. By

further incorporating an optional camouflaged external surface, the apparatus effectively serves as a wildlife blind or hunting blind. Still further, the modular multi-function apparatus can be used in a partially disassembled and reconfigured condition, wherein the toroidal base ring is being used as an open flotation device to support a person on water, and the remainder of the apparatus is being used as an enclosed flotation device or weather-resistant gear closet. The apparatus can also be used as a portable cage, terrarium, aquarium, greenhouse, frost shield, and the like. These applications can be facilitated by the inclusion of an integral or removably attached cover, such as a transparent cover to enable use as a greenhouse, or a fine mesh cover to enable use as a cage for small animals or insects. Note that such a fine mesh cover can also be used as an insect shield (e.g., mosquito net) when using the device as a shelter, incubator, and the like.

Operation as a Water Collection, Storage, and Processing Apparatus:

The modular multi-function apparatus can be used to provide potable water by capturing, purifying, and/or storing precipitation (or other sources of water), wherein additional collection area is optionally provided by an outwardly extended safety cover.

Additionally, the modular multi-function apparatus can be used in conjunction with a transparent cover and a liquid collection vessel to produce potable water by first condensing onto the transparent membrane the water vapor emitted from moist materials placed within the apparatus and passively heated by solar radiation, and then collecting the resulting condensate in the collection vessel. The collection vessel can be supported by the cable-stayed focal point support; however, it can be alternatively supported, such as by attaching it to the transparent cover, which is particularly useful when the moist materials are optionally heated by concentrated energy at the focal point. Note that the apparatus described in this

paragraph also can be used as a dehydrator, dryer, or curing chamber by providing a means for exhausting vapor from the chamber, such as a partially open cover, or an open valve or loading port.

Alternatively, a disassembled and reconfigured modular multi-function apparatus can be used to provide potable water by collecting precipitation and/or dew, wherein the collection area of the apparatus is greatly increased as a result of separating its basic modular components. Note that accessory membranes, such as removable covers, removable reflective membranes, and/or removable reflector chambers, can be attached to the various toroid rings of the disassembled modular apparatus to provide a water collection surface.

Operation as a Wind Turbine:

A reconfigured modular multi-function apparatus can be used to harness wind energy, wherein a lightweight accessory wind turbine generator device is mounted via the cable-stayed focal point support within the inflatable safety cage, which is supported horizontally, facing the wind, by the remaining modules of the apparatus. Conduits can be provided for transmitting electrical and/or mechanical power to other accessory apparatus.

Alternatively, a reconfigured multi-function apparatus can be used to harness wind energy, wherein the lower inflatable toroidal support ring is utilized to structurally stabilize a very lightweight collapsible (membranous) accessory wind turbine, which is mounted aft of the inflatable safety cage on a horizontal accessory rod to facilitate wind-pointing.

Additionally, a reconfigured multi-function apparatus can be used to harness wind energy, wherein an accessory wind turbine device is supported within the inflatable toroidal support ring, which has its wind-facing side movably attached to

a vertical line support to enable wind-pointing, and which further utilizes a plurality of inflatable rings from the safety shield attached to its aft side both to augment airflow through the turbine and to further enhance wind-pointing.

Further, a reconfigured multi-function apparatus can be used to harness wind energy in a manner similar to that described in the preceding paragraph, but further including additional inflatable rings, optionally from the safety cage, located between the line support and the wind-facing side of the toroidal support ring to promote venturi-type flow augmentation through the wind turbine, and to further enhance wind-pointing.

Note that a collapsible lightweight wind turbine can be formed by attaching a plurality of flexible membranous blades to one of the inflatable toroidal support rings in such a manner so as to provide twist in each blade (i.e., the blade angle decreases with increasing radius) both to enhance aerodynamic performance and to facilitate connection to a central axial hub.

A lightweight wind turbine such as described in the preceding paragraph can be used to produce electrical power, wherein the wind turbine is attached to a generator mounted on a horizontal shaft, which is movably connected to a vertical cable support to enable wind-pointing, and to permit the apparatus to be elevated into higher velocity wind streams.

Alternatively, a collapsible lightweight wind turbine can be formed by attaching the tips of a plurality of simple, generally non-twisted, flexible membranous blades to one of the inflatable toroidal support rings, wherein the plurality of blades is economically fabricated primarily from a single flexible membrane.

The lightweight wind turbine as described in the preceding paragraph can be attached to a generator, wherein the wind turbine is attached to a generator mounted on a horizontal shaft, which is movably connected to a stand formed in part by a vertically oriented accessory rod attached to the basic inflatable reflector apparatus and stabilized by a plurality of cables.

Additionally, a lightweight wind turbine can be formed by attaching a slotted, pre-formed membrane having a central

mounting hub to the front side of the inflatable toroidal support ring, and by further attaching a structural safety net having a central hub to the aft side of the inflatable toroidal support ring, wherein the two central hubs are used to stably mount the wind turbine to the shaft of a generator.

The slotted-membrane wind turbine as described in the preceding paragraph can be configured such that the turbine blades are formed by locally slitting and pre-deforming a substantially conical membrane.

Alternatively, a slotted-membrane wind turbine can be similarly configured to that noted above, but wherein the turbine blades are formed by locally slitting and deforming a substantially planar membrane.

Alternatively, a slotted-membrane wind turbine can be configured similar to those described above, but wherein the turbine blades are formed by locally slitting and deforming a shallow, concave, substantially spherical membrane.

As yet another alternative, a slotted-membrane wind turbine can be configured similar to those described above, but wherein the turbine blades are formed by locally slitting and deforming a deeply concave, substantially spherical membrane that is alternatively attached to the aft end of the toroidal support ring so as to not interfere with the stabilizing structural safety nets mounted to the front and aft sides of the toroidal support ring.

Operation for Miscellaneous Applications:

The modular multi-function apparatus can be used as a high-gain directional sound-amplification device, wherein an accessory microphone is attached at the focal point and connected to an amplifying headset to listen, for example, to the auditory chirp of a bird. Note that the naked ear can also be placed in proximity to the focal point to hear distant and/or faint sounds.

Alternatively, the modular multi-function apparatus can be used as a fermentation apparatus by attaching an anaerobic airlock / pressure-relief valve to the upper central membrane.

Note that the portable fermentor apparatus optionally can be deployed (i.e., floated) on water to provide temperature stabilization.

Additionally, the modular multi-function apparatus can be used to sieve or filter liquid and/or solid materials by attaching suitable accessory meshes and/or other filter media to the apparatus.

Further, the modular multi-function apparatus can be used as a floating aquatic chamber to hold live fish.

Alternate Methods for Constructing the Spherical Support and Safety Shield:

An alternate modular inflatable multi-function apparatus can be configured having a low-inflation-volume alternate spherical support and an simplified alternate inflatable safety cage, wherein the low-inflation-volume spherical support is formed by connecting a plurality of inflatable toroidal rings of decreasing major diameter, and the simplified inflatable safety cage is formed by connecting a plurality of inflatable toroidal rings of substantially equal minor and major diameter.

Another alternate modular inflatable multi-function apparatus can be configured having an alternate inflatable spherical support and an alternate inflatable safety cage, each of which comprises an inner membrane and an outer membrane joined by a plurality of spaced, continuous circumferential, membranous ribs (i.e., cylindrical, conical, or annular membranes) to form a plurality of optionally interconnected compartments within each structure.

Yet another alternate modular inflatable multi-function apparatus can be configured having an alternate inflatable spherical support and an alternate inflatable safety cage, each of which typically comprises an inner membrane and outer membrane, which are joined to each other at their peripheral edges to form an inflatable pressure envelope, and which are further joined by a plurality of internal, finite, circumferentially spaced, membranous ribs (i.e., substantially planar radial membranes at discrete circumferential positions)

to hold the inner and outer membranes in a predetermined shape, and to form (typically) a plurality of optionally interconnected compartments within each structure.

Still another alternate modular inflatable multi-function apparatus can be configured, wherein the spherical support alternatively comprises a plurality (e.g., two) of stacked, progressively smaller basic reflector apparatuses, and wherein the safety shield alternatively comprises a plurality of alternate basic reflector apparatuses having removable reflective membranes and/or removable reflector chambers which are removed and stowed to allow light to strike the primary reflector.

FIG. **18** depicts an alternate modular inflatable multi-function apparatus comprising a reflective membrane integrated with a low-inflation-volume combination spherical support and focal point support, wherein the inner portion of the reflective membrane is supported above the spherical support in a pressure-deployable arrangement, and the outer portion of the reflective membrane is intermittently attached to the spherical support in a mechanically deployable arrangement.

Figures 19A-D Alternate Safety Cages:

FIG. **19A** depicts an alternate modular multi-function apparatus having an integral alternate inflatable safety cage, wherein a plurality (e.g., four) of substantially linear inflatable tubes are integrally connected to the toroidal support ring of the basic reflector apparatus and to an upper inflatable toroidal ring to form a lightweight tubular structure, and wherein several of the openings within the lightweight tubular structure, are covered with a flexible mesh or net, both to provide a physical barrier around the focal point, and to enhance the structural stability of the integral safety cage. Note that by making the safety cage integral with the toroid, both structures can be inflated simultaneously by providing one or more interconnecting gas ports between the structures. This configuration significantly enhances safety by preventing the use of the apparatus without a substantially

fully deployed safety cage.

FIG. **19B** depicts an alternate modular multi-function apparatus having a removably attached alternate inflatable safety cage, wherein a plurality of linear (but optionally curved) inflatable tubes are integrally connected to both an upper and a lower inflatable toroidal ring to form a removable lightweight tubular structure, and wherein several of the openings within the lightweight tubular structure are covered with a flexible mesh or net, both to provide a physical barrier around the focal point, and to enhance the structural stability of the removable safety cage.

FIG. **19C** depicts an alternate modular multi-function apparatus having a removably attached alternate inflatable safety cage, wherein a plurality of linear inflatable tubes connected to an upper and a lower inflatable ring form a lightweight truss structure, and wherein several of the openings within the lightweight truss structure are covered with a flexible mesh or net, both to provide a physical barrier around the focal point, and to enhance the structural stability of the removable safety cage.

FIG. **19D** depicts an alternate modular multi-function apparatus having a removably attached alternate inflatable safety cage comprising a plurality of linear inflatable tubes integrally connected to both an upper and a lower inflatable toroidal ring to form a removable lightweight tubular structure, wherein several of the openings within the side of the tubular structure are covered with a light-attenuating flexible transparent membrane, and the upper opening of the tubular structure is covered with a membranous grid or grating to provide off-axis light attenuation.

Tapered Support and Leveling Rings:

The basic inflatable reflector apparatus can be supported by a plurality of inflatable tapered support and leveling rings, wherein the thinnest portions of the stacked tapered rings are located at one circumferential position, whereby the apparatus can be progressively inclined to a nearly vertical orientation

by progressively inflating the tapered rings. Alternatively, the device can be oriented in a nearly horizontal position by substantially deflating the rings. Note that the tapered rings can be inflated simultaneously using one valve by providing interconnecting gas ports between the rings, or inflated separately via individual gas valves for each tapered ring.

Alternatively, a basic inflatable reflector apparatus can be supported by a plurality of inflatable tapered support and leveling rings, wherein the inclination of the basic reflector apparatus is substantially minimized by alternately positioning the thinnest portions of adjacent stacked rings at opposite circumferential locations, but wherein the inclination of the basic reflector apparatus optionally can be maximized by positioning the thinnest portions of the stacked rings at one circumferential location. Note that the rings can also be used to level the apparatus when placed on an inclined surface, such as a hill or roof.

Figures 20A-B Alternate Combination/Dual-Use Safety Cages and Device Supports:

FIG. **20A** depicts an alternate modular multi-function apparatus having an alternate integral inflatable safety cage and a substantially identical alternate integral inflatable spherical support (not shown), both of which comprise two orthogonally connected semicircular tubes optionally integrally attached to the basic reflector apparatus. The apparatus can also have an alternate inflatable focal point support (not shown) comprising two localized or discrete inflatable pressure vessels removably attached to the basic reflector apparatus for supporting via brackets a rod diametrically spanning the basic reflector apparatus.

FIG. **20B** depicts another alternate modular multi-function apparatus having an alternate removably attached inflatable safety cage and a substantially identical alternate removably attached inflatable spherical support (not shown), both of which comprise two orthogonally connected inflatable semicircular tubes integrally attached to an inflatable toroidal ring. The

apparatus can also have an alternate means for supporting a rod (not shown) diametrically spanning the basic reflector apparatus, wherein the rod is removably attached via a bracket or other fastening means (not shown) to the inflatable toroidal ring of the safety cage.

Yet another alternate modular multi-function apparatus can be configured having an alternate inflatable means for supporting the apparatus and a substantially identical alternate inflatable focal point support, both of which comprise a removably attached adjustable truss comprising a plurality (e.g., three) of linear inflatable tubes, wherein each inflatable tube has a plurality of individually inflatable compartments with separate inflation valves as a means for adjusting its length.

Still another alternate modular multi-function apparatus can be configured having an alternate inflatable means for supporting the apparatus and a similar alternate inflatable focal point support, each of which comprises a removably attached inflatable tube stabilized by a plurality of tensioned lines or cable stays. Note that two or more inflatable tubes may be used to enhance stability or provide structural redundancy.

Alternate Non-Inflatable Collapsible Combination Safety Cages and Device Supports.

An alternate modular multi-function apparatus can be configured having an alternate collapsible rigid safety cage and a substantially identical alternate collapsible rigid spherical support, each of which comprise a plurality (e.g., five) of semicircular rigid elements rotatably attached (e.g., pinned) to one side of the inflatable toroidal support ring of the basic reflector apparatus at diametrically opposed pin joints, and which further comprise a plurality of cords or cable stays connected to the semicircular rigid elements and to the basic reflector apparatus to stabilize the collapsible structure.

An alternate modular multi-function apparatus can be configured having an alternate globe-shaped combination

collapsible rigid safety cage and spherical support comprising a plurality (e.g., twelve) of semicircular rigid elements, which are rotatably attached (e.g., pinned) to each other via pin joints located above and below the basic reflector apparatus along the focal axis of the device, and which are further attached to the inflatable toroidal support ring of the basic reflector apparatus both to support the reflector apparatus and to stabilize the collapsible structure.

Figures 21A-D Alternate "Globe-Type" Collapsible Rigid Element Combination Safety Cage and Device Supports:

FIGS. **21A** and **21B** depict an alternate configuration of the modular multi-function apparatus comprising a sub-ambient pressurized removable reflector chamber (third species) removably attached via hooks, clips, or the like, to the equatorial rim and the bottom pole of an optionally collapsible, globe-shaped, truss-like, support structure couched within an inflatable toroidal support ring.

FIG. **21C** depicts an alternate configuration of the modular multi-function apparatus comprising a sub-ambient pressurized removable reflector chamber (first species) having its upper side removably attached via hooks, clips, or the like, to the equatorial rim and its lower side similarly removably attached to a lower parallel rim of an optionally collapsible, globe-shaped, truss-like, support structure couched within an inflatable toroidal support ring.

FIG. **21D** depicts an alternate configuration of the modular multi-function apparatus comprising a super-ambient-pressurized, removable reflector chamber (second species) removably attached via hooks, clips, or the like, to the equatorial rim of the globe-shaped, truss-like, support structure couched alternatively in a ground depression, such as may be dug in sand.

Figures 22A-G Alternate Cable-Stayed Focal Point Supports:

FIG. **22A** depicts an alternate collapsible, cable-stayed focal point support (second species) comprising a square, rigid frame removably attached to the upper and lower surfaces of an inflatable safety cage using four pairs of cords, wires, or cable stays, whereby various accessory elements can be supported in proximity to the focal point.

FIG. **22B** depicts an alternate collapsible focal point support (third species) comprising a circular gimbal (i.e., a self-leveling pivoting frame) movably attached via pin joints to a circular rigid frame, which is removably attached to the upper and lower surfaces of an inflatable safety cage using four pairs of cords, wires, or cable stays, wherein an accessory element supported by the gimbal in proximity to the focal point can be self-leveling as shown, or optionally adjusted and held in a predetermined orientation using an optional adjustment and securing means (not shown), such as a friction clamp at one of the pivot joints.

FIG. **22C** depicts an alternate collapsible focal point support (fourth species) comprising a circular gimbal (i.e., a self-leveling pivoting frame) movably attached via two pin joints to four pairs of cords, wires, or cable stays, which are removably attached to the upper and lower surfaces of an inflatable safety cage, wherein an accessory element supported by the gimbal in proximity to the focal point can be self-leveling.

FIG. **22D** depicts an alternate collapsible focal point support (fifth species) comprising a rigid square frame removably attached to the upper and lower surfaces of an inflatable safety cage using four pairs of cords, wires, or cable stays, and further comprising an internally reflective, articulated structure attached to the upper side of the rigid frame, whereby accessory elements can be supported in a horizontal (i.e., level) or other predetermined orientation, and the radiant energy entering the lower end of the reflective articulated structure can be redirected to the bottom of an accessory element (not shown), such as a pan, to improve performance.

FIG. **22E** depicts an alternate collapsible focal point

support (sixth species) comprising a small bracket or ring attached via four pairs of cords, wires, or cable stays to the upper and lower surfaces of an inflatable safety cage, whereby various accessory elements (not shown) can be supported in proximity to the focal point.

FIG. **22F** depicts an alternate collapsible focal point support (seventh species) comprising a short rod, tube, or length of cable attached via four pairs of cords, wires, or cable stays to the upper and lower surfaces of an inflatable safety cage, whereby various accessory elements (not shown), such as a kettle, can be suspended or otherwise supported in proximity to the focal point.

FIG. **22G** depicts an alternate collapsible focal point support (eighth species) comprising two substantially fixed small brackets or rings, each of which is attached via three (or other number) pairs of cords, wires, or cable stays to the upper and lower surfaces of an inflatable safety cage, and further comprising an adjustable wire loop attached between the two brackets or rings, whereby various accessory elements, such as a cooking or heating vessel, can be supported in a self-leveling manner in proximity to the focal point. Note that the wire loop can optionally have a cinching means (not shown) for securing the cables around an undersized accessory element.

An alternate collapsible focal point support (ninth species) can be configured comprising a flexible wire or cable basket removably attached via six pairs of cords, wires, or cable stays to the upper and lower surfaces of an inflatable safety cage, whereby various accessory elements and/or materials to be heated, such as a cooking vessel, pre-packaged food items, and/or certain solid foodstuffs, can be securely supported in proximity to the focal point in either a random or predetermined orientation.

Figures 23A-B Waveguide and Secondary Reflectors:

FIG. **23A** depicts a basic first embodiment reflector apparatus operating in super-ambient pressure mode to focus

light rays into an accessory waveguide device connected to the upper transparent membrane in proximity to the focal point of the apparatus.

FIG. **23B** depicts an alternate basic first embodiment reflector apparatus having a pressure-deployable convex secondary reflective membrane centered within the transparent membrane of a super-ambient pressurized reflector chamber, wherein light rays entering the apparatus are progressively concentrated by the primary and secondary reflectors into an accessory waveguide device connected to the center of the primary reflector in proximity to the focal point of the modified (compound) reflector apparatus. Note that the waveguide depicted herein can optionally be a lightweight fluid-filled tube, instead of the conventional coated glass or polymer fiber(s).

Figures 24A-D Operation as a Fluid Pump:

FIG. **24A** depicts a basic first embodiment reflector apparatus modified with one-way fluid valves (i.e., check valves) to facilitate inflation, to prevent accidental deflation, and to facilitate use of the apparatus as a manual fluid pump.

FIG. **24B** depicts a modified basic first embodiment reflector apparatus configured as a manual fluid pump illustrating the fluid intake stroke, wherein the central membranes are manually separated (i.e., extended outward) to draw fluid (typically air) into the central reflector chamber through the upper valve.

FIG. **24C** depicts a modified basic first embodiment reflector apparatus configured as a manual fluid pump illustrating the fluid exhaust stroke, wherein the central membranes are manually forced together (i.e., forced inward) to expel or exhaust fluid (typically air) from the central reflector chamber through the upper valve.

FIG. **24D** depicts a modified basic first embodiment reflector apparatus configured as a manual fluid pump

illustrating the fluid exhaust stroke, wherein the central membranes are manually forced together (i.e., forced inward) to expel or exhaust fluid (typically air) from the central reflector chamber through the lower valve into an attached accessory tube, which may be connected to any suitable accessory device (not shown) requiring inflation.

Figures 25A-B Accessory Membranes for Enhanced Water Collection and/or Shelter:

FIG. **25A** depicts a basic first embodiment reflector apparatus further including a plurality (e.g., six) of attached membranes or covers, which are shown extended in a petal-like arrangement to enhance liquid collection by augmenting the capture area of the apparatus, but which can also have various optical properties (such as color, transparency, opacity, emissivity, reflectivity, selective reflectivity, and the like) and, thus, can be used to enhance or enable numerous optical functions of the apparatus.

FIG. **25B** depicts a basic first embodiment reflector apparatus further including a large extended rectangular (or other shaped) multi-layer insulated membrane or sheet attached to the upper surface of the multi-function reflector apparatus to greatly enhance liquid collection in the form of precipitation, dew, or frost. Ties are shown for supporting or elevating the periphery of the membrane; however, one or more inflatable tubes may be used to support the membrane in a cupped configuration. Note that the upper surface of the membrane (and/or many other surfaces of the modules of the present invention) can have a high emissivity surface to enhance the collection of dew or frost at night by radiative condensation processes. Further, note that the multi-layer insulated membrane can also serve as an emergency thermal blanket, insulating ground cloth, protective tarp or cover, and the like. Additional membranes and/or membranes of any other practical shape may also be used.

Note that a basic first embodiment reflector apparatus can

be configured further including a large extended, optionally multi-layer insulated, membrane or sheet supported at its edge by a plurality of inflatable tubes, such as those described above, to provide a modified apparatus having a cupped configuration to facilitate water collection. Similarly configured apparatus can also be used as a self-supporting shelter or suspended to form an umbrella.

Figures 26-27 Miscellaneous Apparatus

FIG. **26** depicts a modified first embodiment reflector apparatus **92** further including optional accessory elements for facilitating the collection and storage of water, including a peripheral gutter **96** having a drain port for connection to a conduit **84**, which is shown further connected to the lower valve to permit water collected in the gutter to be transferred to the reflector chamber for storage. An optionally valved conduit extending through the toroid can also be use to transfer water effluent to the reflector chamber for storage.

FIG. **27** depicts a modified first embodiment reflector apparatus configured as a portable sealed work chamber having a pair of attached gloves and a covered access port incorporated into an optionally removably attached upper transparent membrane.

Figure 28A-B Self-Supporting Automated Sun-Tracking Devices:

FIG. **28A** depicts a modular multi-function apparatus (with the inflatable safety cage and the cable-stayed focal point support omitted from the figure for clarity) having an optional automated means for tracking the vertical motion or elevation of the sun (i.e., a single-axis sun-tracking apparatus), wherein the modular multi-function apparatus further includes a motor-driven cable connected between the upper portion of the apparatus and its supporting toroidal base ring, at least one motorized drive pulley typically attached to the toroidal base ring, and a sun-sensing controller electrically connected via

electrical conduits both to the motorized drive pulley and to an electrical power supply, such as a rechargeable battery and/or photovoltaic panel. Note that the toroidal base ring is configured to hold water such that, when filled, it provides a substantially frictionless support for the inflatable spherical support module, which floats on the water-filled base ring. Note that opposite sides of the toroidal support ring of the basic reflector apparatus are connected to the toroidal base ring via flexible cords or cables to stabilize the upper portion of the apparatus relative to the lower toroidal support ring, which can be secured to the ground, for example, by cables and stakes (not shown), or by other means.

FIG. **28B** depicts a modular multi-function apparatus (with the inflatable safety cage and the cable-stayed focal point support omitted from the figure for clarity) having an optional automated means for tracking both the vertical and horizontal motion of the sun (i.e., a dual-axis sun-tracking apparatus), wherein the modular multi-function apparatus of Figure **28A** having a single-axis tracking apparatus further includes an additional larger water-filled base ring on which the first base ring floats, an additional motor-driven cable connected between the primary base ring and the larger secondary base ring, and one non-driven and one driven pulley, the latter of which is electrically connected via electrical conduit to the sun-sensing controller and electrical power supply.

Figures 29A-C Suspended Automated Sun-Tracking Apparatus:

FIG. **29A** depicts a modular multi-function apparatus (with the inflatable safety cage and the cable-stayed focal point support omitted from the figure for clarity) having an alternate automated means for tracking both the vertical and horizontal motion of the sun (i.e., a dual-axis sun-tracking apparatus), wherein the modular multi-function apparatus of FIG. **28A** having a single-axis tracking mechanism is rotatably suspended via a cable system between an overhead support, such as a tree branch, and a staked ground support to enable substantially frictionless

motion about the vertical axis, and further includes an additional motor-driven cable connected between the toroidal base ring and one non-driven and one motor-driven pulley, both of which are supported by ground stakes, and the latter of which is electrically connected via electrical conduit to a sun-sensing controller and an electrical power supply.

FIG. **29B** depicts a basic first embodiment reflector apparatus having a dual-axis (i.e., vertical and horizontal) sun-tracking mechanism, wherein the basic reflector apparatus is suspended via a cable system between an overhead support, such as a tree branch, and a staked ground support to enable substantially frictionless motion about the vertical and horizontal axes, and further comprises two motor-driven cables (one for each axis of rotation), and two motorized drive pulleys (one for each axis of rotation), both of which are supported by ground stakes and are electrically connected via electrical conduit to a sun-sensing controller and an electrical power supply.

FIG. **29C** depicts a basic first embodiment reflector apparatus having a polar-aligned, single-axis, sun-tracking mechanism (i.e., the axis of the tracking mechanism is optionally aligned with the poles or rotational axis of the earth), wherein the basic reflector apparatus is suspended via a cable system between an overhead support, such as a tree branch, and a staked ground support to enable substantially frictionless motion about an axis parallel to the Earth's axis of rotation, and further comprises one motor-driven cable and one motorized drive pulley, the latter of which is supported by a ground stake and is electrically connected via electrical conduit to a sun-sensing controller and an electrical power supply.

Figures 30A-D Materials of Construction

FIG. **30A** depicts a typical, substantially polymeric, multi-layer composite material from which the apparatus can be

constructed, comprising from bottom to top: a heat-sealable layer of material (such as polyethylene, and the like), a load-bearing structural membrane (such as Nylon, Mylar®, and the like), a smooth reflective layer (such as provided by vapor-deposited aluminum, and the like), and a protective upper coating (such as lacquer, polyethylene, and the like), which optionally may also be heat-sealable.

FIG. **30B** depicts an alternate, substantially polymeric, multi-layer composite material from which the apparatus can be constructed, comprising from bottom to top: a heat-sealable polymer material, a longitudinally oriented load-bearing structural polymer membrane, an intermediate polymeric bonding or interface material, a transverse-oriented load-bearing structural polymer membrane, a reflective metallic layer, and a protective polymer coating which also serves as a heat-sealable layer, whereby the two cross-stacked, directionally-oriented membranes increase strength and tear resistance of the composite membrane.

FIG. **30C** depicts a fiber-reinforced multi-layer composite material from which the apparatus can be constructed, comprising from bottom to top: a heat-sealable polymer material, a bi-axially oriented load-bearing structural polymer membrane, an intermediate polymeric bonding or interface material, a layer of reinforcing fibers shown, for example, in a bi-axial weave, a second intermediate polymeric bonding or interface material, a second bi-axially oriented load-bearing structural polymer membrane, a reflective metallic layer, and a protective polymer coating which also serves as a heat-sealable layer, whereby the fiber reinforcement greatly improves the strength and tear resistance of the multi-layer composite membrane.

FIG. **30D** depicts a fiber-reinforced composite material from which the non-reflective portions of the apparatus can be constructed, comprising a layer of reinforcing fibers in, for example, a bi-axial weave integrally imbedded in a heat-sealable

polymer matrix material, whereby an economical, high-strength, tear-resistant composite membrane is provided for the non-reflective portions of the apparatus. Note that this material can also optionally incorporate a reflective surface.

Finally, to facilitate many of the applications of the modular inflatable field-deployable apparatus of the present invention as described herein, it should be noted that various common electronic and/or mechanical accessory devices or apparatus can be integrally or removably incorporated into any apparatus of the instant invention in any useful quantity, location, and combination thereof. Such optional electrical and/or mechanical accessory devices include, but are not limited to, pumps, fans, drive motors, timers, thermostats, flow controllers, photovoltaic cells, movable louvers or iris apparatus (for controlling flow or radiation), and other useful elements. To further enhance the collection, storage, processing, and distribution of water or other liquids, it should be noted that various common liquid handling and processing devices can also be integrally or removably incorporated into any apparatus of the instant invention in any useful quantity, location, and combination including, but not limited to, liquid pumps, pipes, tubes, funnels, valves, pressure gauges, flow meters, flow controllers, filters, and other useful elements.

Thus, the extensive applicability of the fundamental modular inflatable multifunction field-deployable apparatus has been disclosed.